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Devoted to Applied Botany and Plant Utilization

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The Pollen Harvest

At least three million people in the United States suffer from seasonal allergy caused by inhalation of air-borne pollens of many species. Each affected person is a potential ultimate consumer of refined pollen products, and the annual collecting of pollen for this purpose amounts to $80,000 to $100,000 for the collectors.

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Wind-blown pollens acquired commercial importance less than 40 years ago as a result of the development of specific preventive treatment of hay fever and pollen asthma with pollen extracts. Before that time collection of these powdery pollens was a decidedly incidental occupation. Even the bees who gather and exploit to the utmost the concentrated food elements in pollen pay little or no attention to the vast tonnage from anemophilous (wind-fertilized) plants. Occasionally the hover flies (Syrphidae) may be seen devouring, one at a time, the pollen grains of corn or timothy, but they are not dependent on this type of pollen, being equally satisfied with that of the nectariferous composites and numerous other entomophilous (insect-fertilized) species. The annual collecting quota of any and all insects is necessarily very small. Even in large-scale artificial hybridization projects it has seldom been found practicable to accumulate large quantities of pollen because of the comparatively short time—usually a matter of a few days—that pollens remain viable.

Indians of various tribes in the Mississippi Valley are known to have gleaned the swamps for the pollen of cattail (*Typha*) to use it in making pollen soup or gruel. However, the labor expended was more than the food yield would seem to justify, thus placing the item near the top of the Indian luxury list. Perhaps enough was gathered to afford a surplus for exchange, but, if so, we can only conjecture as to what this particular dry soup stock may have brought in cash or trade. In the Southwest the Apaches still collect cattail pollen to use in their religious ceremonies and are said to be interested in any opportunity to sell part of their sacred powder to the Navajos and other tribes who also use it for ritual purposes. The present Apache price (18) is one teaspoonful for 25¢, one tablespoonful for $1.00. In spite of this seemingly high rate the demand frequently exceeds the supply so that the Indians are driven to substituting the pollen of piñon (*Pinus cembroydes* Voss) and of other local plants. This adulteration would be difficult to detect except with a microscope. Actually the price of 25¢ per teaspoonful for cattail pollen is less than the present quotation by professional collectors.

A steady though limited demand for dry pollens in bulk has developed during the past 35 years. Engineers often use anemophilous pollens for testing the efficiency of air-conditioning apparatus. Appreciable quantities are required for chemical research, as in fractionation of constituent allergenic elements; also for immunologic experiments. Most of the wind-borne pollen now collected, however, is used in the preparation of pollen extracts, the kinds and quantities collected being governed for the most part

by the proved idiosyncrasies of the several million persons in the United States and Canada who are afflicted with pollen allergy.

Pollens and Pollen Allergy

Pollens as Allergens. Air-borne pollen grains are now recognized as the principal, though not the sole, exciting cause of seasonal inhalant allergy—hay fever and seasonal asthma. The degree of allergenic toxicity of the more active types of pollen is so great and the presence of pollen in the air is so imperceptible that even physicians hesitated for many years in accepting the pollen etiology of hay fever. It seemed impossible that such small quantities of any irritant could cause such pronounced and severe physical symptoms. Not until skin tests, with their spectacular wheal reactions, became routine in the diagnosis of pollen disease, were both physicians and laymen convinced. To fully appreciate the degree of allergenic activity of pollen it is necessary only to note that strong positive skin reactions have been elicited by an amount of ragweed pollen extract obtainable from five pollen granules, approximately 1/100,000 mg.

Annual Periodicity of Pollen Disease. The regular seasonal recurrence of hay fever is the most distinctive feature of the disease—the one first noticed by laymen. While it is not true that the onset of symptoms occurs on the very same calendar day each year, just as the swallows are supposed to return to Capistrano, yet there is a distinct period of suffering which recurs annually as regularly as the flowering of the outdoor vegetation. This finding early suggested that the disease might be caused by some phenomenon connected with the life cycle of plants. Pollen allergy was first described in England where it appears in its most severe form at the time of hay harvest, in early summer, and is traced to the pollens of the hay grasses. Hence the popular and now widely accepted name "hay fever", which name is obviously inappropriate for inhalant allergy that may be caused by any kind of pollen except that of grasses. In this country the fall type of hay fever, being much more frequent than the summer form, was the first to be recognized.

Geographic Incidence. Another early observation was that hay fever victims could sometimes obtain partial relief or complete remission of symptoms by a change of residence. At first this regional aspect of the disease was supposed to be due to differences in climatic factors, but we now know that the beneficial effects found in any locality are wholly matters of escape from, or reduction in, the degree of contact with the particular pollen or pollens to which the mover-about is hypersensitive. Suffering in the individual allergic subject increases or decreases roughly in direct ratio to the amount of active (on him) pollen in the air that he inhales. Hay fever symptoms can be provoked in a very few moments by deliberate inhalation of pollen, or placing tiny amounts on the nasal linings, but it may require an hour or more to relieve severe paroxysms after the sufferer is placed in a pollen-free environment. Another geographic aspect of pollen disease, not noted by earlier observers, it that the season of distribution of particular pollens varies greatly with latitude and altitude.

Specificity of Sensitiveness. One person out of every twenty or thirty in the United States and Canada is allergic to pollens of some kind, but not all allergics are affected by the same kind of pollen. A ragweed pollen victim may or may not suffer with hay fever symptoms when he is exposed to bluegrass pollen or oak pollen. He may or may not react positively to a skin test with grass pollen or oak pollen. A grass pollen victim may be affected by grass pollens only, or, in addition, he may react with equal

severity to pollens of other botanical orders or families. In general, it may be said that sensitization is most likely to be induced by the kind of pollen which is inhaled in the largest amounts over the longest period of time. But this statement must be immediately qualified because of the fact that pollens vary greatly in their toxicity, or power to sensitize. Some seem to have no allergenic qualities at all.

FIG. 1. Apache Indian collecting cat-tail pollen for ceremonial use. Apache Reservation, near McNary, Arizona. (*Photo by Tad Nichols*).

The specificity of the response of the hypersensitive individual is seldom limited to the pollen of a single botanical species, as of white oak (*Quercus alba* L.). It usually includes in varying degree all species of a genus and frequently extends to the whole family, occasionally even to the whole order. Thus it is possible to obtain a strong positive skin reaction with numerous pollen species which have never been encountered by the person being tested. This is satisfactorily explained by the fact that these out-of-area pollens have allergenic substances similar to those of the botanically related species which the victim normally encounters and to which he has actually been sensitized. In general, the specificity of skin reactions parallels clinical specificity so that skin reactions to tests with various suspected types of pollen will furnish a reasonably accurate index of clinical sensitiveness. Inhalant tests with dry pollen may be used as a control on the skin test findings, but if the hay fever sufferer experiences severe symptoms only during the

period of local pollination of a species to which he shows marked skin reaction, the evidence of specific sensitivity is usually considered conclusive.

Specific Treatment. Preseasonal hyposensitization treatment for pollen disease is usually carried out annually with a graduated series of doses of specific pollen antigen (pollen extract) which are administered hypodermically [1] during a period of weeks or months preceding the season of maturity of the pollen against which the patient needs protection. A modification of this method is that of following the preseasonal schedule with sustaining doses of pollen extract not only during the season of pollen exposure but throughout the year, the intervals between doses, as well as the size of the doses, being adapted to the response of the patient. The pollen extract administered to any particular patient may be made from the pollen of only one species or it may be made of several species of the same genus or the same family, depending on which and how many species the person ordinarily encounters in excessive amounts. The combination of several unrelated pollen antigens in a single solution for treatment is not usually advisable. Separate treatment schedules for separate types of pollen, particularly when they are encountered at different seasons, are most likely to produce good results. In any case the physician who diagnoses and treats inhalant allergy must carry in stock or have access to a variety of pollen antigens—fewer if he has only a local patronage, more if he draws patients from a wide area.

Methods of Clinical Evaluation

Field and Air Research. Pollens of the more common anemophilous plants, like those of the ragweeds and meadow grasses, have long been recognized as important allergens. By noting that a large number of people experience severe nasal or bronchial allergy during the whole period of pollination of these ubiquitous plants, it was necessary only to investigate their suspected role by a change of residence or ocean voyage during the season of pollination of the offending plant. Skin tests have in such cases served only to help confirm what was already evident. Full confirmation consists in good results with specific desensitization treatment. But for tracing the causes of hay fever occurring at unusual seasons and for assessing the role of any of the less abundant species, it has not been found sufficient to depend on skin testing and on field observations as to the relative abundance and regional distribution of plants. Since the suffering of the allergic person is caused by the pollens that he actually inhales, the most logical approach to his problem would seem to be that of determining just what pollens are in the air at the time and in the area where the victim has his difficulty. Pollen allergy thus poses a local problem in air pollution. Local differences in air content can be traced to such variable factors as soil, altitude, rainfall, temperature, wind movement and wind velocity.

Local Pollen Surveys. The most satisfactory method of carrying out a comprehensive local pollen survey is that of simultaneous field observations and air analysis. Field observations over a period of years of the dates of pollination and relative productive ability of local species afford a good check on the results of air research—the daily determination throughout the spring, summer and fall of the number of granules of each kind of pollen in the air at a given place. For this atmospheric research a volumetric sampling device may be used, such as the Wells Centrifuge, but no satisfactory filter or precipitating volumetric device has been developed. So

[1] Oral pollen therapy which was popular for a few years has been generally discarded.

for practical purposes a standard technic of gravity sampling with vaseline-coated slides has been developed. The standard technic used and recommended by the Research Council of the American Academy of Allergy (1) has now been widely adopted by allergists, by State and city boards of health and by others interested in pollen aerobiology. It consists essentially of a standard slide holder, 24 hours exposure of vaseline-coated (1″×3″) microscope slides, counting of all pollens caught on a unit area of one square centimeter (or equivalent) and, usually, the use of standard factors for converting the square centimeter counts into approximate volumetric (cubic yard of air) equivalents.

Botanical Aspects of Aerobiology

Anemophily vs. Entomophily. Buoyant powdery pollens are only one link in the chain of anemophily. The flowers that produce this type of pollen are usually marked with characters as obviously adapted to wind dispersal as are the pollens themselves. For this reason recognition of flower types is fundamental to recognition of pollen types.

Entomophilous flowers attract insects by means of colorful petals, strong odors and by "palatable" nectar and pollen. Once the insect comes to the flower he encounters floral arrangements and mechanisms which in most cases favor cross-fertilization by the most direct route. Anemophilous flowers have none of these characters. They are usually simple, incomplete—without petals or attractive color, often without sepals, without nectaries and lacking perfume. They are usually, though not always, unisexual, with the staminate and pistillate flowers on separate plants (dioecious) or with both sexes more or less remotely placed on the same plant (monoecious). The staminate inflorescence is usually a loosely balanced panicle, raceme, spike or flexible pendant ament or catkin which favors easy dislodgment of ripened pollen. A few plants are adapted for both wind and insect fertilization, but such plants are rarely abundant producers. So for practical purposes of allergy the final test of anemophily is the incidence and distance of dispersal of pollen in the air.

Morphology of Pollen Grains. The typical pollen grain at maturity is a spherical or oval cell consisting of a tough protective outer coat (extine) and a thin inner sac (intine) holding a tiny drop of protoplasm with two nuclei—a cell nucleus and a germ nucleus. The protoplasm is very responsive to changes in atmospheric humidity, readily absorbing and discharging water in amounts of 50 to 100 percent of that of the dry grain. With the increased volume which is gained by a pollen grain upon absorption of water vapor the elastic intine merely stretches itself and exerts pressure on the weaker or more flexible parts of the extine wall. The extine usually has one or more, often three, deep grooves, whose thin sides allow a sort of accordion accommodation. In the center of each of these grooves is a germinal pore. This may be an actual opening in the extine or very thin area where the intine may push through and send out a loop or tube for carrying the germ nucleus to a waiting ovule. The number and arrangement of grooves and pores and the type of surface markings—spines, knobs, reticulations, etc.—together with the diameter of the pollen grain, are the principal means of microscopic identification.

Entomophilous pollen grains when mature usually adhere one to another by means of long sharp spines or because of a viscous substance adherent to the granules, or both. Anemophilous pollens lacking any surface adhesive and having only rudimentary spines have little or no tendency to clump together, so are easily dispersed and held in suspension by the

air as soon as they are dry. Small grains are more buoyant than large ones, the rate of fall in still air varying directly with the square of the diameter, other factors being equal. Surface irregularities and low density tend to increase buoyancy.

Dispersal. The discharge of ripened pollen from flowers is not a continuous process during anthesis, but a daily cycle occurring at a definite time of day unless interfered with by adverse weather conditions. The anthers of timothy (*Phleum pratense*) begin to emerge from the flowers long before daylight, and ragweed (*Ambrosia elatior* L.) anthers burst soon after sunrise, while redtop (*Agrostis alba* L.) waits until about 2:00 P.M. The factors which are favorable to rupture of anther cases and discharge of pollen are sunshine, low air humidity and moderate temperatures. The total period of anthesis may, for a single plant, last only a day or two, or it may be prolonged for weeks. For a species it may last even longer locally because of local variations in moisture, soil and temperature.

If wind velocities are low at the time of pollen discharge much of the day's crop will fall immediately to the ground. The higher the wind velocity the greater the degree of air contamination. Air turbulence caused by surface irregularities—buildings, trees and other objects—tends to hold pollens in suspension until they are caught by ascending thermals and carried upward to distances varying from three to six thousand feet. Pollen ceilings are determined by the upper limit of turbulent air and thus may be higher on one day than another because of varying lapse rates. On clear days the pollen ceiling may often be observed from an airplane—not that the pollen itself may be seen, but because of its accompanying particulate matter. The visible haze line is the pollen ceiling, above which only stray granules may be found. Numerous atmospheric tests made from airplanes show that the distribution of pollen in the upper air is never uniform nor is the diminution from the ground level to the ceiling a gradual decline. The invisible pollen clouds are shifted about in much the same way as are visible vapor clouds. Vertical tests of the air will frequently show higher pollen concentrations at four or five thousand feet than at one or two thousand feet. In fact, the large cumulus clouds carry much heavier loads of pollen than the surrounding air (10).

Since pollen particles are easily lifted to heights of several thousand feet it is not difficult to account for lateral drift to a distance of 50 to 100 miles. Tests above Lake Michigan have shown almost equal concentrations of pollen in the air 30 miles from land as at the same altitudes over land. Thus pollen may be blown from an area where it is abundant into an adjacent area where there are few or no producing plants, as into southern edges of the heavily wooded areas of the northern States and Canada.

Identification. The same physical characters of pollen grains—size, weight and surface irregularities—which determine their mode of transport also serve the aerobiologist for purposes of identification of pollen grains caught in samples of air debris, as well as the manufacturing pharmacist and allergist in identifying and determining the purity of pollens purchased on the open market.

Pollen grains may be examined under the microscope either in their dry and characteristically shrunken form or expanded with any aqueous mounting solution, with or without stain. Diagnostic characters are often intensified by staining. For some species moistening has little effect on the pollen grain, but in others the effect is pronounced. Sizes are usually determined by measuring equatorial diameters of expanded granules by means of an eyepiece micrometer

FIG. 2. Giant ragweed (*Ambrosia trifida*), also known as "horseweed", is a tall coarse annual, widely distributed in moist waste and cultivated land in the central and eastern States. Pollinates mostly in August and September.

which has been calibrated against a ruled stage micrometer. Occasionally it is necessary to note polar diameters as well as equatorial diameters.

Excellent enlarged drawings of pollen grains, showing the surface characters of all important wind-pollinated species, have been published by Wodehouse (23, 24). Photomicrographs of pollens appear in various textbooks on allergy. But for purposes of identification no picture can possibly compare in usefulness with an authentic specimen of pollen. From such a specimen the investigator may prepare temporary or permanent mounts in any way that will suit his purposes. The ideal equipment is a set of pollen samples collected directly form local plants as they come into flower. Even in one season a good variety of authentic reference specimens will thus be secured for study and comparison with any unknowns that may be encountered. There is actually little need to preserve mounted pollen specimens, since fresh ones can be easily prepared from a very small stock of dried pollen.

The American Academy of Allergy maintains a type collection of pollens at the University of Illinois where anyone interested in aerobiology may obtain specimens without charge [2].

Collecting

Sources. The pollen harvest is not the culmination of a deliberate program of seed sowing and careful cultivation. Only a very small part of the total hay fever pollen crop comes from the producer's own fields and gardens. Obviously a plant species capable of contaminating the air over any sizeable region must produce pollen freely and be abundantly distributed over many thousands of acres. This is true of trees as well as shrubs, grasses and weeds. A sample of the extreme ratio between supply and demand is furnished by bur oak (*Quercus macrocarpa* Michx.). A single large tree of this species could easily supply year after year all the bur oak pollen needed by all the hay fever sufferers in North America. Collectors are usually content with the yield from plants that have grown naturally in neglected areas within reasonable range of their headquarters.

Occasionally West Coast collectors have chosen to cultivate certain eastern weeds and grasses rather than trade for pollen produced in areas where the weeds are native and abundant. Extra good yields might in some cases justify the extra cost. It is sometimes more desirable to buy the crop on a few acres of meadow or even to cultivate a plot than to use inferior volunteer grasses. Whether the allergenic quality of weed pollens could be standardized or increased by growing plants under special conditions and in special soils has not been fully determined (22). Nor have genetic experiments been attempted with such objects in view. Pollens of cultivated crops other than the cereals and meadow grasses are rarely requested.

Incidental Collecting Methods. While small amounts of pollen for hybridizing are regularly obtained by tying glassine or paper bags over the flowering heads of plants, this method is seldom followed in the collection of hay fever pollen. Ripened pollen which has been discharged from the anthers but not dissipated into the air may be removed from certain types of plants with a vacuum cleaner, but the catch is likely to include a high percentage of foreign matter that will be difficult to separate from the pollen. For trees like hazelnut and oak it is necessary only to gather the mature catkins and spread them out in a warm dry place for 24 hours. Grasses and some kinds of weeds will also yield well

[2] Dr. Ralph F. Voigt, University of Illinois, 808 South Wood Street, Chicago 12, Illinois.

FIG. 3. Giant ragweeds may reach a height of 15 feet on soil which is moist, rich and loose.

merely by drying of the flowering clusters or spikes [3].

In the Appalachian area the hand method of collection is widely used. The collector starts out in the morning as soon as the dew dries off the blossoms and before any breeze has jostled the plants. He, or more likely she, carries a pan covered with very fine screen wire of bolting cloth on which the ripe blossoms are tapped. Surprisingly large quantities of excellent quality ragweed pollen are secured in this way by the combined efforts of experienced collectors. Each worker sells his product at an agreed price per ounce or per gram to a jobber. These part-time collecting and indirect marketing procedures are comparable to those followed throughout the southern Appalachians in the crude drug business. The secret of success of hand collecting in this particular area is in the early morning calm of the mountain valleys—a situation which could not be duplicated anywhere in the prairie States.

Drying and threshing of flowers whose pollen is not readily separable from the anthers is a last resort method used mostly in obtaining small stocks of relatively unimportant pollens such as the insect-pollinated composites. The tradition about roses and goldenrod being the prime cause of hay fever is so firmly fixed in the popular mind that many persons insist on being tested with these pollens. Occasionally there is a real need of testing and even of desensitization with pollens of garden and greenhouse flowers because of allergies developed by florists who come in direct contact with them.

Laboratory Method. A "greenhouse", or ripening laboratory, for natural maturing and processing is almost a prime necessity in harvesting commercial quantities of the common wind-blown pollens. Several good-sized rooms must be provided so that more than one species can be cared for at one time without danger of contamination. The rooms must have plenty of direct sunlight and the ventilation carefully controlled. Humidity must be kept low enough to encourage the ripening of the pollen but not so low as to wilt the plants, since they must be kept alive and producing for two or three days. Long pans or metal troughs of water hold the flowering stalks which have been cut to a uniform length of 18 to 24 inches. These troughs are built with inclined sides which allow the flowering heads to hang beyond the edge of the trough and drop their pollen on strips of glazed paper, glass or other suitable surface between the rows of pans.

Transport of plants from the field to the ripening laboratory must be accomplished without undue wilting or other damage to the blossoms or foliage. If the distance is long considerable care must be exercised to keep the plants moist and cool. If too moist and too closely packed in warm weather they are likely to heat to the point of charring in a few hours. In gathering and transporting the plants no attempt is made to conserve the pollen from anthers which have already opened. The whole effort is to keep the cuttings fresh until time for the next day's discharge of pollen which usually occurs in the early morning. In any case good judgment, born of experience, is needed in deciding just when to gather maturing flowers in order to obtain maximum yields. As soon as the plants of a given batch are exhausted, in one day, two days or three days, all pollen adhering to the flowers is shaken off and the processing of the pollen begun immediately.

[3] The collection method suggested by Coca (7), consisting of drying and grinding ripe flowering spikes, has often been quoted but is not recommended either for high yield or for good quality.

Cleaning and Drying

Purity. During 1947 Dr. Milton V. Veldee, chief, Biologics Control Laboratory, National Institutes of Health, called together a representative group of allergists and botanists engaged in pollen collection to formulate standards for the collection and preservation of pollen. This Committee has recommended (21):

"Contamination with mixed pollens of other species should not exceed 1.0 per cent, or 0.5 per cent with a single pollen, as determined by microscopic count, except that when ragweed pollen is the contaminant the amount of this pollen present shall not exceed 0.1 per cent. There are a few instances involving field-collected pollens when single species pollens cannot be collected to meet these specifications because simultaneously pollinating plants are growing in close proximity to each other. When unavoidable excessive contamination occurs due to this cause, the purchaser of the pollen should be informed.

"The amount of extraneous plant material from the same species present in the pollen should not exceed 10 per cent for pollens obtained from those species which do not freely shed their pollens and not more than 5 per cent from free-shedding species.

"Pollen should be free of all contaminants not related to the species of plant involved, such as leaves, dirt, and similar substances. An exception is recognized with those plants whose growing habits make contamination with dirt unavoidable; example, creeping pigweed".

Removal of extraneous matter is accomplished mostly by sifting. Ore sieves of 40 to 200 mesh are useful for this purpose. However, even the finest ore sieves will allow the passage of fine soil particles, so it is occasionally necessary after sifting to resort to sedimentation with ether or carbon tetrachloride. These solvents do not injure the pollen in any way. They merely remove fats and resins which contain no water-soluble allergenic substances.

Desiccation and Stability. The importance of rapid drying of freshly collected pollen is strongly emphasized in the Veldee report which sets up as a standard a minimum of 1.0 percent moisture in pollen stock stored or offered for sale. Collectors are as a rule not equipped to determine the exact moisture content of their pollens, so the Biologics Control Laboratory of the National Institutes of Health, Bethesda 14, Maryland, has offered to assay one-gram samples submitted with the idea of checking the efficacy of the drying system being used.

"The factors which determine the stability of the allergenic component of a pollen are not fully established. However, it has been shown that storage without adequate drying speeds the rate of denaturation, and more particularly so, if stored at relatively warm temperatures. Extrinsic moisture (due to humidity, dew, or rain) provides favorable conditions for fermentation and souring of the pollen due to the activity of contaminating micro-organisms. Intrinsic moisture (moisture contained in the pollen) is necessary for enzymatic (chemical) activity within the pollen grain. These denaturing activities can be slowed, if not actually arrested, by storage at temperatures well below freezing or by the removal of the moisture to below the critical level for enzyme and micro-organism activity. Storage in an oxygen-free atmosphere would be of benefit. The age of the pollen is probably of secondary significance, provided the moisture is promptly and adequately removed.

"At the time of collection the pollen grains are living cells inside of which a certain amount of metabolic (enzymatic) activity is in progress. Intrinsic moisture is involved in this activity and may even be produced by being split off from other compounds during cellular metabolism. This intercellular activity has been termed respiration. The purpose of prompt drying (desiccation) is to arrest permanently this chemical activity".

Purchasers usually specify pollen of the most recent crop, but it is quite certain that the allergenic potency of properly dried pollens lasts for many years. The Veldee recommendations merely require that the date of collection be shown on the container.

Desiccators. A large percent of the moisture in pollen may be removed by placing small lots in shallow dishes and setting in full sunshine. Oven drying is widely practiced, using temperatures up to 65° C. A special desiccator which

passes heated air over the pollen and then dries the air with silica gel has been described by Beresford and Cooke (3):

"The apparatus consists of an airtight box with brackets and shelves for holding trays and storage bottles, over which a stream of warm, dry air is circulated. A door on one end permits the manipulation of trays and bottles in a minimum of time. A blower on the top of the box draws air from its interior (the drying chamber), forces it through a tank containing the drying agent (the drying tank), from which it passes over heating coils to enter the bottom of the drying chamber. A thermostat in the latter, adjustable from the outside without opening the door, controls the operation of the heating coils and thus the temperature within the box. Baffles are arranged in the tray brackets which force the air to circulate over the tops of the trays. A sheet of asbestos above the bottom opening disperses the warm, dried air entering the box and prevents the formation of a hot spot on the lower tray. In other words, the machine is so designed that warm, dry air entering at the bottom is forced over the tops of the two trays which contain pollen, then is withdrawn, dried, heated, and again put into circulation".

A simpler and much less expensive type of desiccator is the regular laboratory Pyrex glass vacuum desiccator in which a phosphorus pentoxide (P_2O_5) is used as a desiccant and which is evacuated to a pressure of three millimeters of mercury or less. This apparatus is satisfactorily operated at room temperature.

Color of Dried Pollen. If stored pollen darkens rapidly it is evident that undesirable changes are taking place in the pollen. Grass pollens are particularly susceptible to this color change. Properly dried pollens will retain their original color as well as their antigenic qualities almost indefinitely.

Variations in Potency. Regardless of the method used in preserving pollen and regardless of its age or appearance, different lots of pollen of the same species differ somewhat in their activity as determined by skin tests and by controlled clinical tests. However, since no satisfactory standard of potency or official method of assay has been agreed upon, few if any purchasers accept or reject pollen on the basis of potency assays of any sort.

Marketing the Crop

Crude drug jobbers 50 years ago sold most of their dried roots, leaves and bark to druggists and doctors who prepared their own medicaments in a back room or instructed the patient in home preparation. Many doctors even gathered their own herbs. Gradually, however, the manufacturing pharmacist demonstrated the superiority of his abilities and facilities so that the doctor no longer finds it necessary to hunt for goldenseal or dig May apple roots. The druggist likewise now leaves the processes of extraction of alkaloids and preparations of elixirs mostly to the manufacturing pharmacist who buys botanicals in large quantities only through jobbers. But the allergy field is so comparatively new that primitive methods have not been entirely abandoned. While druggists have seldom attempted to manufacture these biologic products, many allergists still prepare their own extracts of pollens and other allergens in spite of the difficulties involved in maintaining strict sterility. Some allergists even collect their own pollen. So at present the potential market for pollen includes numerous allergists, who maintain institutional and private allergy clinics, as well as a dozen pharmaceutical manufacturers and smaller commercial concerns which specialize in the manufacture and distribution of allergenic extracts.

A large share of the season's crop of pollen is sold before it is collected. The larger users anticipate their needs for a whole season and place their orders during the winter. This insures an adequate supply of fresh material from the oncoming crop. The current price lists of leading pollen collectors quote on some

FIG. 4. Short ragweed (*Ambrosia elatior*), also known as "common ragweed", is a well distributed annual weed of fields, gardens, roadsides and waste land throughout the agricultural regions of North America, particularly east of the Rocky Mountains. Pollinates in August and September, as late as November in Florida and along the Gulf of Mexico.

200 species. On small lots the price of the more easily collected pollens is as low as 25¢ per gram, with liberal discounts on quantities of 100 to 300 grams. Those which are most difficult to collect range as high as $5.00 per gram, but very few of the wind-blown pollens are priced above $1.00 per gram. Prices of particular species will be noted in the accompanying systematic discussion of hay fever plants and pollens.

Collectors who are best informed about the market estimate the total annual commercial pollen business as amounting to $80,000 to $100,000.

Pollen Extracts

Qualities of Pollen Extracts. The basic simplicity of a pollen extract can best be appreciated by noting that when a few granules of dry pollen are brought into contact with the moist mucous membrane of the nose the slightly saline nasal secretion promptly extracts enough of the allergenic content of the pollen grain to cause a local congestion of blood in the tissues with accompanying itching which leads to sneezing and a copious discharge of secretion.

If pollen is placed in water its allergenic constituents immediately go into solution. This solution is pollen extract, but if there is no chemical in the solution to inhibit bacterial growth the extract will not be suitable for hypodermic injection and will deteriorate very promptly. The antigenic substances in a plain aqueous extract are likewise unstable so that steps must be taken to insure stability of potency over a reasonable period of time, as with other biological products. A further quality of acceptable pollen extracts is freedom from substances that cause irritation to the skin and subcutaneous tissues when the extract is used in routine treatment.

Methods of Preparation. A physician making extracts for use in his own office or clinic may make sure of the sterility, stability and non-irritating qualities of his extracts by any process that he chooses to use. He usually starts by defatting the fresh pollen with ether or carbon tetrachloride. The aqueous extraction fluid employed is often a phenolized alkaline-saline fluid or a combination of such fluids with glycerin in equal or other proportions. Another widely used extraction method contains only five percent of dextrose and one-half percent phenol. The strength of the resulting solutions (extracts) is governed by the proportion of pollen in a given quantity of menstruum—usually one, two or three grams of pollen to 100 cc. of menstruum. Extraction is carried on for a day or two with continuous or frequent agitation. Grinding of the pollen is no longer deemed necessary. The pollen grains are removed from the solution by filtering through filter paper.

Sterility is attained by filtering the extracts through a Seitz filter. Extracts are stored at 0° C. and diluted to such strengths as may be required for testing and treatment in particular cases. A few allerggists preserve their extracts by lyophilization and storage of the resulting powder in sealed vacuum containers.

Standardization of Potency. For most biologic medicinal products satisfactory standards of potency have been developed, assays being possible either by chemical or biologic technic. For such a seemingly simple medicinal as pollen extract, standardization would appear to offer little difficulty, but at present there are several methods in use, none of which is satisfactory enough to be acceptable to a majority of allergists. Nor is it likely that a unit of strength will be adopted until more is known about the chemical nature of the exciting agent in pollen. The original assumption that the toxic element was a protein has long since been discarded. Tuft (19) says: "Other studies have demonstrated the presence of a complex carbohydrate in ragweed pollen, possibly a polysaccharide, which gives specific cutaneous and

nasal reactions in ragweed-sensitive individuals and can be used in treatment."

The unit of Noon, once widely used, is defined as the amount of pollen toxin extracted from a millionth of a gram of pollen. A more flexible dilution-by-weight method of statement has largely supplanted this unit standard. Usually the designations used are 1 : 100, 1 : 1,000, 1 : 10,000, etc. Both the Noon unit and the dilution-by-weight standard are inaccurate, since the allergenic activity of extracts made from different lots of pollen may vary considerably. Many physicians still use the method of statement of total nitrogen in milligrams per cubic centimeter. This necessitates the employment of unwieldy decimal fractions to four or five places. Two valid objections to the nitrogen standard are recognized, first, that its reliability stands or falls on the protein theory, and, second, that loss in potency of an extract is not accompanied by a similar loss in nitrogen.

A more recently proposed method of standardization involves assay of the protein nitrogen content of extracts, but evidence of its accuracy is still lacking. Actually the degree of individual sensitivity to pollen extract—the so-called threshold of tolerance—varies so greatly from individual to individual that any possible exact assay of potency of pollen extracts has little practical meaning as far as aiding in the control of safe and effective dosage. In practice the physician begins treating each patient with extremely small doses and feels his way, adjusting each dose for each patient by the local and general response of that patient to the previous dose. In effect this means that any extract used on any patient must be experimentally standardized on that patient. This is why allergists have been satisfied to proceed with crude methods of standardization.

Government Supervision and Standards. Commercial manufacturers of pollen extracts operate under biologic licenses granted by the United States Public Health Service. This authority issues regulations for the strict control of manufacturing conditions, personnel and processes, also for proof and maintenance of sterility and potency of the extracts. Each package must bear an expiration date, the period of stability depending on the type of preservatives used. Pollen extracts which are not made under government license and regulation may not be sold interstate.

Wind-pollinated Trees and Shrubs

For the practical purposes of allergy, trees and shrubs, except the shrubby species of the Chenopodiaceae and Amaranthaceae and some of the shrubby Compositae, are definitely set apart from the wind-pollinated herbaceous plants. This is due to their decidedly early season of bloom as a group, as well as to the comparatively low toxicity of the pollens of most species. Some appreciation of the relative importance of the tree pollens can be gained by the statement that in Chicago 23 percent of the pollen in the air is from trees, while no more than two percent of specific pollen sensitiveness found in the area can be traced to them. In Washington, D. C., where considerably more than half of the annual atmospheric contamination is from trees, only four percent of the hay fever cases are primarily due to tree pollens (4). Yet in individual cases, reactions to tree pollens are sometimes alarmingly severe, and in a few areas certain tree species are frequently involved. Exposure to tree pollens is unique in that a single plant in the immediate vicinity or place of employment may easily account for all the difficulties of a person who may be sensitive to the pollen. In general the pollen grains of trees are larger and less buoyant than those of herbaceous plants.

Some of the evergreens begin to shed pollen in December, not only in the southern States but in the high Sierras.

The early broad-leaved trees are often in bloom by the second week of January in the Gulf States, and the late ones do not finish until June in the northern States. A very few species pollinate in late summer and fall. The collector can usually count on a definite annual sequence of anthesis of the various local species, but particular species cannot be depended upon to shed pollen at a definite time each year. The date of onset of pollination of the earlier trees may vary as much as three weeks before or after the average date because of favorable or unfavorable weather conditions. The later trees are not so greatly influenced by weather. Patience and watchful waiting are required on the part of the collector, but when the trees do begin to yield, the task of harvesting the pollen is a very simple one, usually with excellent returns.

Conifers. Without exception the gymnosperms are wind-pollinated, and in most cases the pollen is shed in copious quantities, but since only one family has been recognized as possessing allergenic pollen, attention is here directed only to the conifers (Pinaceae). In this family the staminate flowers, which consist of small cones with anther sacs on the underside of the cone scales, are distinct from the seed-bearing cones. Pollen grains of most of the conifers fall into one of two morphological types. Pines, spruces, firs, mountain hemlock (*Tsuga mertensiana* Sarg.) and deodar cedar (*Cedrus deodar*) are monoecious and have large pollen grains with two air sacs, or bladders. The grains vary from 50 to 100 microns in diameter exclusive of the bladders. The junipers (dioecious), bald cypresses, redwoods and related genera have smaller spherical pollen grains, 20 to 40 microns in diameter, with very thin extine and heavy intine. Several genera of the latter type are quite potent causes of inhalant allergy, while allergic clinical sensitiveness to any species of the bladder type is extremely rare. Indeed, if it were not for three cases of reported clinical allergy evidently due to pine pollen, which were reported to be controlled by pine pollen treatment, allergists would be inclined to regard all conifer pollens of this type as entirely lacking in toxic quality. In the single well-authenticated case of pine sensitiveness (14) the patient, who lived in the Lake Tahoe region, California, showed strong positive skin reactions to the pollens of Monterey pine (*P. radiata* D. Don.), knob-cone pine (*P. attenuata* Lemm.), sugar pine (*P. lambertiana* Dougl.), yellow pine (*P. ponderosa* Laws.), Scotch pine (*P. sylvestris* L.) and tamarack pine (*P. murrayana*), although he was exposed mostly to the pollens of yellow pine and tamarack pine. Treatment with pollen extract of yellow pine and tamarack pine was said to afford complete protection.

The large quantities of pollen produced in conifer forests can best be appreciated by seeing it on the surface of ponds and quiet streams. Crater Lake in Oregon sometimes has large pollen rafts hundreds of feet long floating on the surface.

Incense cedar (*Librocedrus decurrens* Torr.), found at high elevations in the Sierras and other western mountains, matures large amounts of pollen in midwinter, frequently causing severe allergy symptoms to residents and visitors at Yosemite National Park.

Mountain cedar pollen can be bought at 40¢ to $1.00 per gram, Port Orford at $1.00 per gram, but incense cedar pollen seems not to be on the market. The globular pollen grains of the three species, belonging to related genera, are

FIG. 5 (*Upper*). Harvesting short ragweeds from fallow land for indoor ripening of pollen.
FIG. 6 (*Lower*). Collecting naturally ripened short ragweed pollen.

very similar in microscopic appearance. That more difficulty from other relatives of the junipers, such as the sequoias, has not been noted would seem to be explained partly because the trees are seldom native or widely cultivated in areas of heavy population.

Palms. Of the dozen or more native arborescent species of palm in the southern and southeastern States, particularly in Florida, none has been proved to contribute any appreciable amount of pollen to the air or to be of local importance in allergy. Of the introduced species only date pollen (*Phoenix dactylifera* L.) has been incriminated. In spite of the reports of "appreciable incidence of pollinosis" from this pollen in Galveston, Texas, there are no confirmatory reports of its activity from the date-growing areas of Arizona and California. Collection of pollen is a simple matter; no laboratory equipment is necessary. Pollens of *P. dactylifera* and *P. canariensis* are listed by one collector at $2.50 per gram.

Willows and Poplars. The willows, which are semiwind-pollinated and of wide distribution, are of only minor importance in allergy. Numerous species, some uncovering their "pussy" catkins early and others much later, cause a long potential season of distribution. When the small three-pored granules appear on the atmospheric sampling slides, they are almost invariably in clumps, which accounts for their lack of buoyance. Skin tests will occasionally elicit positive reaction, but supporting clinical evidence for specific sensitivity is usually lacking. No attempt has been made by allergists to compare the allergenic qualities of the various species of willow. It is also impracticable to attempt to identify the pollen grains as to species. Recent collectors' lists carry "*Salix* spp., *S. alba*, *S. nigra*, *S. discolor*", priced at $1.00 to $2.00 per gram.

The poplars, including aspens and cottonwoods, are all dioecious and wholly wind-pollinated. They reach anthesis at the same time as the early willows and shed moderate to large quantities of pollen. Little attention is paid to the native aspens, *Populus grandidentata* Michx. of the northern States and *P. tremuloides* Michx. of the northern and Rocky Mountain areas, or to the cottonwoods and balsam poplars of the central and eastern States. The staminate horticultural forms of Carolina poplar (*P. candicans* Moench.), which have been freely planted for street trees, cannot do much harm, since either they produce mostly sterile blossoms or the catkins fall off before the anthers mature. But in the West and Southwest skin reactions to cottonwood pollen, as well as hay fever symptoms caused by it, are sometimes very severe. The most active western species seem to be *P. sargentii* Dode, *P. fremontii* S. Watts and *P. macdougalii* Rose. Whether the western pollens have greater toxicity or whether the exposure is greater in that area has not been determined. At any rate, in some cases western cottonwood-sensitive persons respond just as strongly to eastern cottonwood pollen as to that of western species. The pollen granules of all poplars are very similar in microscopic appearance, although varying slightly in size from species to species. Bulk pollens, which are very easily collected, are available from eight or ten poplar species at 80¢ to $1.50 per gram.

Bayberry Family. In sandy swamps along the eastern seaboard, New Jersey to Florida, wax myrtle (*Myrica cerifera* L.) is a very common shrub, sometimes of tree size, with dioecious flowers which shed copious quantities of wind-blown pollen. During the year 1944 at St. Simons Island the author found a larger seasonal total of air-borne wax myrtle pollen than of any other local species, even including ragweed. Yet this pollen has never been offered for sale nor even

FIG. 7. Russian thistle (*Salsola pestifer*), also known as "tumbleweed", is a globular annual found in sandy soil throughout the U.S.A. Abundant in the "dust bowl" area and frequent in all areas where irrigation or dry farming is carried on. Pollinates July to September.

mentioned in allergy literature except that wax myrtle was included in a calendar of pollination for New York City prepared by Hodgson for VanderVeer, Cooke and Spain (20). The pollen grains so closely resemble those of hazelnut and birch that they have usually been overlooked in aerobiologic studies. But how the shrubs could have been almost completely overlooked in field studies and their pollen entirely neglected in clinical investigation is not easy to explain—perhaps because they are not abundant near centers of population. Another shrubby species of this family which grows on barren soil in the northern and northeastern States is sweet fern (*Comptonia peregrina* (L.) Coulter). This shrub also sheds pollen freely and could easily be a factor in hay fever. As in the case of wax myrtle it has apparently received no notice or study whatsoever except in Wodehouse's morphologic monograph (24).

Walnut Family. The pollens of walnuts and butternuts (*Juglans*) as well as of hickories (*Carya*), both native and cultivated species, are occasional causes of hay fever of a very severe type. Clinical cases are said to be frequent among the pecan grove laborers of the South and occasional in the walnut-growing sections of California. The monoecious flowers appear with the first leaves in late spring. The pollens of all species, as far as investigation has been made, contain essentially the same allergenic qualities. The grains are large and heavy as compared with those of other broad-leaved anemophilous trees, and the two genera can be easily differentiated microscopically. Black walnut pollen averages about 36 microns in diameter. Its 12 germinal pores are grouped on one side of the grain which is spherical when moist, collapsed when dry, surface rough. Hickory pollen grains vary from 40–50 microns in diameter, each showing three germinal pores equally spaced around the meridian. They are spheroidal when moist, cup-shaped when dry. Collection is easily accomplished by gathering the staminate catkins and allowing the anthers to open in a dry warm place. The species available from collectors include *J. nigra*, *J. regia*, *J. californica*, *J. rupestris*, *C. pecan*, *C. alba*, *C. laciniosa* and *C. glabra*. Prices range from 50¢ to $1.25 per gram.

Australian Pines. The beefwoods (*Casuarina equisetifolia* Forst. and *C. cunninghamia*), comparatively recent introductions from Australia, are now extensively planted in central and southern Florida. Superficially they strongly resemble the conifers, but, according to Wodehouse (25), both the flower and pollen characters indicate a close relationship to the walnuts. They are strictly wind-pollinated, but Florida allergists have found very few positive reactions on testing with the pollen. Although easily collected it is not now listed by the leading collectors.

Birch Family. Except for the alders (*Alnus*), all members of the Betulaceae are regarded by allergists as of only minor or moderate importance in allergy as compared with other trees. Clinical research has proved that the pollen of all species have very similar antigenic qualities. Moreover, the pollen granules of all genera except alder are so similar in microscopic appearance that differentiation is difficult. They are comparatively small (23–26 microns), flattened, with prominent protruding pores which cause the three-pored grains to appear almost triangular and the four-pored grains (alder) almost square. Large yields of all species can be obtained by merely gathering and drying the catkins.

The hazelnuts (*Corylus americana* Walt. and *C. rostrata* Ait.), widely distributed wild monoecious shrubs, are among the very earliest plants to shed pollen in the spring. They are seldom if ever the cause of allergy symptoms,

but in the Pacific Northwest, where several varieties of filbert (*C. avellana*) are cultivated, the atmospheric contribution is sufficient to cause considerable difficulty in February and March, particularly when supplemented in March by enormous quantities of alder pollen from *Alnus rubra* Bung. and perhaps other species. In the northern and eastern States alders are not regarded as important. Hazelnut pollen is offered at 75¢ per gram, filbert at 90¢ per gram, and half a dozen species of alder at from 75¢ to $1.25 per gram.

Hornbean (*Carpinus caroliniana* Walt.) and the ironwoods (*Ostrya*), though widely distributed, are nowhere found growing in dense stands nor are they used for shade or ornament, so their contribution of pollen is negligible. The demand is slight with ample supplies of both species at 70–90¢ per gram.

In the New England area air contamination from the birches (*Betula*) ranks next to that of the elms and oaks. Here they are probably of moderate importance in early spring hay fever, but elsewhere atmospheric studies in the larger centers of population, as well as the smaller places, in practically every State have failed to record any appreciable amount of the pollen in air samples. The collectors list a half dozen of the more common species at 40¢ to $1.00 per gram.

Beech Family. Among the Fagaceae only beech (*Fagus grandifolia* Ehrh.) and the oaks (*Quercus*) are wind-pollinated. Beech trees are widely distributed in the eastern States, but, since the output of pollen is comparatively small and the pollen grains much less buoyant than other anemophilous tree pollens, these trees add very little to the general atmospheric contamination. The pollen interreacts with that of the oaks, as would be expected. The price varies from 50¢ to $1.00 per gram.

All of the many widely distributed *Quercus* species produce copious amounts of pollen which can be easily collected. All have essentially the same allergenic qualities so that the pollen of any species or a mixture of several is found satisfactory for testing and treatment. Severe allergenic reactions are seldom experienced. Microscopic differentiation of the granules is impracticable and seemingly unnecessary for the purposes of allergy. The season of pollination in most areas is long, due to the differing habits of the several abundant local species. Air contamination with oak pollen in many places exceeds that of ragweed pollen both for quantity and length of season. More than 20 species of oak pollen are offered for sale at 45¢ to $1.25 per gram. Pollen could probably be supplied for 50 or 60 species if orders were placed for future collection.

Elms and Hackberries. For the country as a whole elms (*Ulmus*) are probably the most important tree source of hay fever pollen. In most of the cities and villages white, or American, elm (*U. americana* L.) is the choice of all trees for shade and ornament. Thus they bring their active pollen right to our doorsteps, but most of the elms pollinate very early in the spring (early January in the Gulf region) when most people spend very little time out of doors, so that comparatively few persons are sensitized. However, in Texas where anthesis of the locally abundant scrub elm parallels that of ragweed, elm pollen sensitiveness is common. The persons here affected by scrub elm will react equally strongly to elm pollen of any other species. Red elm (*U. serotina* Sarg.), another fall-pollinating species, is scattered through the central South. Its pollen contribution to the air seems to be much less than that of scrub elm. Whether the fall-pollinating varieties of Chinese elm are more than potential sources of allergy has not yet been determined.

FIG. 8. Sagebrush (*Artemisia tridentata*), also known as "mountain sage", is a canescent aromatic shrub of the Rocky Mountain region. Pollinates in August and September.

Elms, unlike most anemophilous trees, have perfect flowers, not in catkins. In order to obtain commercial quantities the flowering twigs must be placed in water and the anthers allowed to mature naturally. Microscopic differentiation of the pollens is possible for some species. Bulk slippery elm (*U. fulva* Michx.) pollen has a distinct fragrant odor. The following species are available at 90¢ to $3.00 per gram: *U. alata* Michx., *U. americana* L., *U. crassifolia* Nutt., *U. fulva* Michx. and *U. pumila*. Water elm (*Planera aquatica* Gmel.) is not mentioned in the literature of clinical allergy. No one offers the pollen for sale.

Hackberry (*Celtis*) pollen has received comparatively little attention in allergy. Bowie (6) reported excessive amounts of it in the air during April in Nashville, Tennessee. There is little evidence of heavy productivity elsewhere. In other southern aerobiologic studies the pollen grains may have been mistaken for those of elm which they slightly resemble. The several species of hackberry are widely distributed, but apparently no one has attempted to see how the allergenic quality of the pollen compares with that of the elms. Pollen of only one species, *C. occidentalis* L., is offered by collectors at $1.00 to $2.00 per gram.

Mulberry Family. A clinical evaluation of the pollens of red mulberry (*Morus rubra* L.) and paper mulberry (*Broussonetia papyrifera* Vent.), the latter a dioecious "weed" tree of southern cities, has been made by Bernton (5) of Washington, D. C., in which city recent atmospheric studies of Kailin (12) have showed large amounts of paper mulberry pollen in the air in April. Field distribution studies of the latter in Oklahoma have been reported by Balyeat and Rinkel (2). Their pollens evidently interreact, but it is not known whether the pollen of osage orange (*Maclura pomifera* Schn.), abundant in the Ozark region, is similarly active. The only atmospheric report on this pollen is that of Bowie (6) who found large quantities of it on atmospheric slides exposed in May at Nashville, Tennessee. The pollen grains of all three species are small and very buoyant and resemble those of the closely related herbaceous hemp (*Cannabis sativa* L.) and hop (*Humulus*

lupulus L.). In aerobiologic studies, however, there need be no confusion with them, since the latter pollinate only in the fall, whereas the trees pollinate in the spring. Collection of pollen is rather difficult. Collectors' prices for red mulberry is $1.00 to $1.75; paper mulberry, $2.00; osage orange, $1.50.

Sweet Gum. *Liquidambar styraciflua* L., a strictly monoecious tree of the wooded areas of the eastern and southern States, produces a fairly large amount of comparatively heavy airborne pollen. Only small amounts have been reported on test slides anywhere within its range, although the grains are unmistakable. The pollen evidently has little if any toxic quality. The price is $1.50 per gram.

Sycamores. Apparently the pollen of any of the eastern, western or naturalized plane trees (*Platanus*) is mildly allergenic. In aerobiologic studies in Philadelphia sycamore pollen grain counts for two successive seasons exceeded that of any other tree species. It is unlikely that this came from the native *P. occidentalis* L. Judging by Wodehouse's (25) discussion it is more likely that it was almost wholly from the cultivated London plane tree (*P. acerifolia* Willd.) which is much used for street planting in eastern cities. Sycamore pollen is smaller and more buoyant that that of any of the other broad-leaved trees except those of the mulberries. The flowers are dioecious, both staminate and pistillate blossoms being clustered in small pendant globes. *P. occidentalis* is priced at 90¢ per gram and up, *P. racemosa* at $1.75 per gram.

Box Elders and Other Maples. None of the maples (Aceraceae) except box elder (*Acer negundo* L.) is strictly anemophilous, even though all of them possess some of the characters of anemophily. Red maple (*A. rubrum* L.) and silver maple (*A. saccharinum* L.) flowers are attractive to insects but often appear too early for insects to assist in pollination. Some species, such as Norway maple (*A. platanoides* L.), produce very meagerly and seem to add nothing

FIG. 9. Hemp (*Cannabis sativa*), frequently referred to as marijuana, is locally abundant mostly in western Iowa, eastern Nebraska and adjacent areas of Missouri and Kansas; an escape from cultivation for fibre. Pollinates July to September.

to the overall air contamination. The pollen of all species is more or less sticky so that the grains tend to cling together, thus limiting its range of distribution. The toxicity of the pollen is evidently quite low. Box elder is priced at 90¢ per gram, other *Acer* species $1.75 to $3.00 per gram.

Ashes and Related Genera. Most of the *Fraxinus* species are dioecious and entirely wind-pollinated, but the other important genera of the Oleaceae, including the cultivated olives (*Olea europea* L.), have many characters of entomophily and are only partially wind-pollinated. All seem to produce allergenically active pollen easily distinguishable microscopically as to genus. Oregon ash (*F. oregona* Nutt.) of the Pacific coast and Arizona ash (*F. velutina* Torr.), often used as a shade tree in Arizona and New Mexico, are probably much more active than the ashes of the central and eastern States. Olive culture in the Southwest causes local exposure to olive pollen. Privet hedges (*Ligustrum vulgare* L.) in the northern States are not regarded as sources of airborne pollen, but in the South large ornamental privet bushes cause considerable suffering to a few persons who are directly exposed. Ash pollen, which is extremely simple to collect, is available at 50¢ to $1.50 per gram for all the more common species. Olive and privet pollens, which are more difficult to collect, are priced at $3.00 per gram.

Insect-pollinated Trees and Shrubs

Scarcely a single common species of woody plant, particularly those with conspicuous flowers, has escaped the attention of those who suffer with seasonal allergy. The important distinctions between anemophilous and entomophilous trees or the fact that pollens from certain species are never found in the air do not constitute valid arguments against the notions of those who insist on diagnosing their own allergy. So allergists sometimes demand pollens of certain entomophilous species merely for the purpose of convincing a particular patient. When positive reactions are obtained with an unusual pollen there is a strong chance that the finding may forthwith be written into the literature without adequate supporting evidence for the allergenic qualities of the pollen. For fruit trees and a few ornamental species there is some possibility of sensitivity being developed on very intimate exposure. Other special situations account for a list of insect-borne pollens being offered for sale for which there is very infrequent or local demand. An example of a local semiwind-pollinated species is mesquite (*Prosopis glandulosa* Torr.) which is said to be important in west Texas. In many cases the top prices of $4.00 to $4.50 per gram, which are charged for the following entomophilous pollens, scarcely compensate the collector for his efforts:

Apple (*Pyrus malus* L.)
Pear (*Pyrus communis* L.)
Peach (*Prunus Persica* S. & L.)
Acacia (*Acacia* spp.)
Red bud (*Cercis canadensis* L.)
Locust (*Robinia pseudacacia* L.)
Tree of heaven (*Ailanthus glandulosa* Desf.)
Sumac (*Rhus copallina* L.)
Eucalyptus (*Eucalyptus* spp.)
Dogwood (*Cornus nuttallii* Aud.)
Catalpa (*Catalpa bignonioides* Walt.)
Elderberry (*Sambucus canadensis* L.)

Grasses and Marsh Plants

The flowers of the Gramineae are unique in their simplicity of form and their effective mechanisms for rapid dispersal of pollen. In a family of strictly anemophilous plants with so many native and introduced species as the grasses (11,000 according to Hitchcock (11), in the U.S.A.), evaluation of the allergenic toxicity and atmospheric contribution of each individual species might seem to pose an insuperable task. The difficul-

ties are accentuated by the fact that the pollen grains of almost all genera and species are so similar in microscopic appearance and often of such similar sizes as to prevent certain identification of the many species of grass pollen grains found in atmospheric sampling. However, the comparative lack of specificity of allergic reaction to grass pollens was early noted. Clinical tests carried out with more than 100 species have shown that in most grass-sensitive cases the individual will react more or less to any or all species. Some experimenters are convinced that the allergenic qualities of all grasses are so nearly the same that therapy may be carried out in any case with any species. Others feel that a few grass pollens have distinct qualities and that of these, Bermuda grass (*Cynodon dactylon* (L.) Pers.) is the outstanding example. The task of the collector is therefore not usually too difficult, since it resolves largely into that of securing sizable quantities of pollen from grasses which produce freely and neglecting most of the others. The number of species qualifying on this basis is small indeed. Most of these fall in the group of the cultivated hay grasses or pasture grasses of the cooler humid portions of the temperate zone. (See Table I). The seasons of pollination of these cultivated species do not coincide perfectly, but very definite successive waves of airborne grass pollen may be quite easily traced to the source plants and checked against the periods of recurrence of severe suffering of grass-sensitive cases. Most of the wild native grasses are very minor contributors to the overall pollen contamination of the air, not because of limited distribution but because they seldom produce pollen freely.

Meadow Grasses. Three species of bluegrass appear on the collectors' lists. Of these Kentucky bluegrass (*Poa pratensis* L.), known as June grass in New England and the adjacent seaboard area,

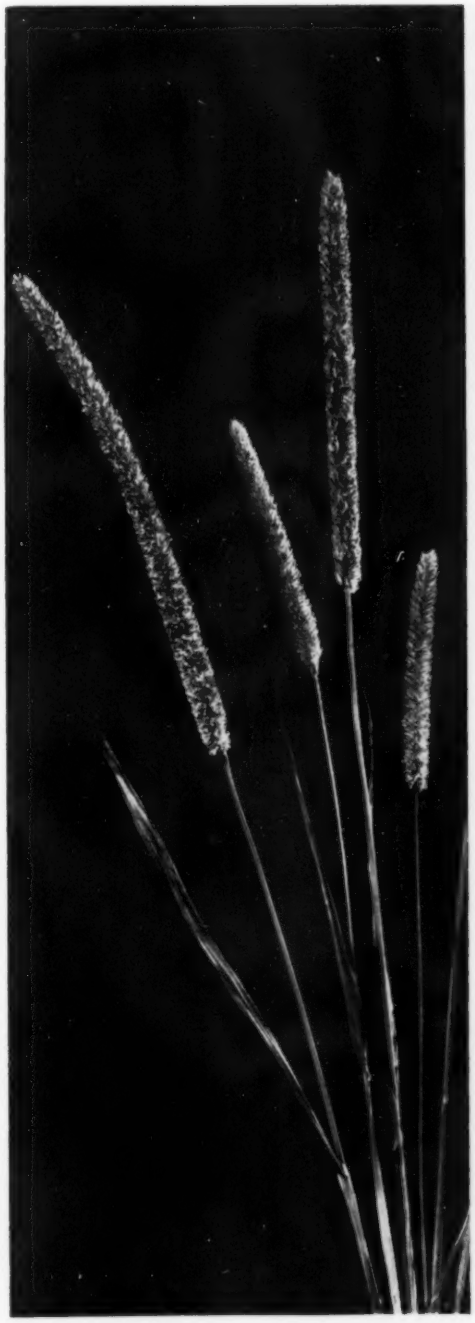


FIG. 10. Timothy (*Phleum pratense*) is a common meadow grass, often found growing along roadsides and in neglected areas, most abundant in the northern and eastern States. Pollinates in June and July.

TABLE I

HAY FEVER GRASSES OF THE UNITED STATES

Common Name	Botanical Name	Time of Pollination	Distribution	Importance in Allergy	Pollen Production
		Principal Tame Hay Grasses*			
Timothy	*Phleum pratense* L.	Late June & July	Northern States	Primary	Abundant
Redtop**	*Agrostis alba* L.	Late June & July	Northern States	Secondary	Abundant
Orchard grass**	*Dactylis glomerata* L.	May & June	Northern States	Primary	Abundant
Meadow fescue**	*Festuca elatior* L.	July & August	Northern States	Small	Scant
Smooth brome**	*Bromus inermis* Leyss.	June & July	Northwest	Secondary	Small
Johnson grass	*Sorghum halepense* (L.) Pers.	July to September	Southern States	Little	Small
		Principal Pasture Grasses*			
Kentucky bluegrass	*Poa pratensis* L.	May & June	Northern States	Primary	Abundant
Bermuda grass	*Cynodon dactylon* (L.) Pers.	Early spring to late fall	Southern States	Primary	Scant
Colonial bent	*Agrostis tenuis* Sibth.	Late June & July	Northeastern States	Not recognized	Scant
Italian ryegrass	*Lolium multiflorum* Lam.	July & August	U. S. except southeast	Secondary, Calif.	Small
Perennial ryegrass	*Lolium perenne* L.	July & August	U. S. except southeast	Secondary, Calif.	Small
Dallis grass	*Paspalum dilatatum* Poir.	April to November, apex May	South	Secondary	Small
Carpet grass	*Axonopus compressus* (Swartz) Beauv.	August & September	Southeastern States	Not recognized	Small
Canada bluegrass	*Poa compressa* L.	June & July	Northern States	Secondary	Abundant
Sheep fescue	*Festuca ovina* L.	June & July	Rocky Mt. States	Very little	Small
		Local Hay and Forage Grasses			
Velvet grass	*Holcus lanatus* L.	June & July	W. Wash. & Oregon	Secondary	Moderate
Sweet vernal grass	*Anthoxanthum odoratum* L.	May & June	New England & Middle Atlantic States	Secondary	Moderate
Wheat grasses	*Agropyron spp.* Gaertn.	June to August	West & Northwest	Minor	Small

* Names, order, and distribution data from Hitchcock's *Manual of the Grasses of the United States.*

** Also important as pasture grasses.

is the most important, not only because of its great acreage in the northeast quarter of the United States, but because of its productive ability and because it contributes so heavily to the first spring wave of atmospheric contamination. Its pollen is also one of the most buoyant of the common grass pollens. Onset of pollination may vary as much as six weeks or more because of differences in latitude and altitude, and as much as ten days in a given area because of seasonal variations in the weather. The season of dispersal is from late May through June in the bluegrass belt. The pollen grains, as of all other grasses, are spherical or oval when fully expanded, the extine is smooth with one germinal pore. The shrinkage pattern is irregular, many grains collapsing by invagination but more of them assuming a " pear " shape with the germinal pore on or near the large end. In bulk bluegrass pollen, like nearly all of the grass pollens, is light yellow. It is priced at 50¢ to 75¢ per gram.

Annual bluegrass (*Poa annua* L.) is a widely distributed, early maturing species, regarded mostly as a nuisance in lawns because of its habit of early yellowing and drying. Though often mentioned in allergy literature, this grass is certainly of very minor allergic importance anywhere. The pollen is difficult to collect, partly because of the small productivity of the plants and very restricted acreage of pure stands and partly because of the short stems and low lying inflorescence. Priced at 75¢ to $1.50 per gram.

Canada bluegrass (*Poa compressa* L.), a coarse introduced and now self-sustaining " weed " species of the northern States and Canada, reaches anthesis about three weeks later than Kentucky bluegrass. The early allergists overlooked the large contribution of this widely distributed grass which is actually far more important as a source of inhalant allergy than several which have been widely used. Easily collected, the pollen is priced at 50¢ to $2.00 per gram.

Orchard grass (*Dactylis glomerata* L.) reaches anthesis at almost exactly the same time as Kentucky bluegrass so that on atmospheric test slides the pollen grains cannot be separated as satisfactorily, even by size, for bluegrass granules are not all 30 microns in diameter, nor all orchard grass granules exactly 34 microns. Of these two species orchard grass is the more copious producer but the more limited in acreage. The pollen is usually priced the same as bluegrass pollen, occasionally lower. Purchases may be made at 10¢ per gram on large quantity orders.

Timothy (*Phleum pratense* L.) matures shortly after Canada bluegrass and approximately a month after Kentucky bluegrass. With it or following shortly after, is redtop (*Agrostis alba* L.). In many places in the north central and northeastern States, timothy alone or timothy and redtop cause a second noticeable wave of grass pollen in the air. The distinction of the pollen grains is a little more marked in this wave, since the average sizes are as follows: redtop grains, 28 microns; timothy, about 34 microns. Timothy, orchard grass and redtop require almost exactly the same climatic and soil conditions as Kentucky bluegrass except that redtop is likely to seek the more moist locations and orchard grass the more shady locations. Timothy and bluegrass are self-sustaining on roadsides and in waste places, whereas orchard grass is likely to be very abundant in cities and towns, and seldom seen on roadsides, meadows or waste land. Collectors' prices for timothy and redtop are about the same as for the grasses mentioned just above. Little ingenuity is required in collection, but some difficulty is encountered with all grass pollens in thorough elimination of moisture.

Sweet vernal grass (*Anthoxanthum odoratum* L.), a grass seldom found west of the Appalachians, is frequently mentioned in allergy literature. It is of little consequence as a hay grass and is more or less of a weed along the eastern seaboard. Its chief distinction seems to be its early maturity—ahead of Kentucky bluegrass. That its importance has been greatly overestimated is suggested by the fact that its pollen is much heavier than that of any of the other commonly recognized hay fever grasses, and proved by the fact that the grass pollen content of the air in the area where sweet vernal grass is most abundant does not increase appreciably until Kentucky bluegrass reaches anthesis. Ample supplies of the pollen are available at 75¢ to $1.50 per gram.

Cereals. As a whole the cereals are of slight importance in inhalant allergy. This is surprising in view of the fact that they are members of the grass family and cultivated on millions of acres of land. Wheat (*Triticum aestivum* L.) is largely if not wholly self-pollinating, and oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) and rice (*Oryza sativa* L.) are largely self-pollinated, while rye (*Secale cereale* L.) and corn (*Zea mays* L.) are abundant producers of pollen. But rye pollen is much larger than that of the meadow grasses and is consequently much heavier. Corn pollen, the most abundant of all, is also the largest and heaviest of all, the granules being approximately 100 microns in diameter and their rate of fall 20 times that of ragweed pollen grains (8). Corn pollen drops from the tassels to the ground like sand, except in extremely strong winds, and is seldom found in the upper air more than a few yards away from the field in which it is matured. The antigenic quality of cereal pollens is as high as that of any of the other grasses, but, since exposure to them is so unlikely, particularly in centers of population, they are rated among the pollen curiosities of allergy, and demand for them is slight. Extremely easy to collect, pollens of corn and rye are usually marked at 50¢ per gram. Wheat, oats and barley are held at $2.00 to $3.00 per gram. Millet (*Chaetochloa italica* Scribn.) is available at 90¢ per gram, and various sorghums (*Sorghum*) as follows: Johnson grass (*Sorghum halepense* (L.) Pers.) at $1.25 per gram, grain sorghum (*Sorghum vulgare* Pers.) at $3.00 per gram, cane (*Sorghum vulgare* var. *saccharatum* (L.) Boerl.) at $3.00 per gram, Sudan grass (*S. vulgare* var. *sudanense* (Piper) Hitchc.) at $1.25 per gram.

Grasses of the West and South. In the drier parts of the Great Basin, where the bluegrasses and timothy will not grow without irrigation, hay is obtained from a number of wild grasses and a few drought-resistant introduced species. The wheat grasses (*Agropyron*) are typical of the former, and smooth brome (*Bromus inermis* Leyss.) of the latter. The pollen of these dry land grasses is not abundant. Collection is much more difficult than with the meadow grasses, but supplies are available at $1.00 to $1.50 per gram.

In the humid areas of western Washington and western Oregon the early meadow grasses include such species as perennial rye grass (*Lolium perenne* L.), which is also common in California, and velvet grass (*Holcus lanatus* L.), which come into bloom early in May with Kentucky bluegrass and orchard grass. Velvet grass is priced at 80¢ per gram, perennial rye grass at $1.00 per gram.

South of the Mason and Dixon Line, except in Appalachian highland, bluegrass, timothy and orchard grass are little used for hay and meadow because of their inability to stand the heat. They are largely replaced by Bermuda grass which is probably the most widely distributed of the tropical and semi-tropical grasses. It can withstand drought

and where encouraged at all overgrows practically everything else. Bermuda grass is one of the most troublesome sources of hay fever pollen throughout the Southwest and in the populated areas of California. It sheds pollen almost throughout the year whenever moisture is sufficient to cause it to flourish. In Arizona there are two distinct seasons—April and September. Strangely enough, the pollen is never produced abundantly, so atmospheric contamination is slight, but local exposure on lawns and in fields and waste places is sufficient to cause a very severe type of grass hay fever. Being difficult to obtain, the pollen is marked higher than that of any other active anemophilous species, some collectors holding it as high as $3.50 per gram.

Miscellaneous Grasses. Other unimportant grass pollens for which there is light demand run the collectors' lists up to 50 or more species, including one to several species of *Bromus, Phalaris, Alopecurus, Festuca, Elymus, Holcus, Paspalum, Panicum, Bouteloua, Tripsacum* and *Spartina.*

Sedges and Rushes. While all species of the sedge family (Cyperaceae) as well as the rushes (Juncaceae), including the wood rushes (*Juncoides*), are wind-pollinated and have long been regarded as potential hay fever plants, the low aerial incidence of their pollens and the lack of evidence of allergic activity have discouraged extensive clinical research with them. In recent price lists no sedge or rush pollen of any species is offered.

Cattails. While the cattails (*Typha*) are distinctly anemophilous, the pollen is comparatively heavy. Its range of dispersal is quite limited, as proved by its very low atmospheric incidence in cities, towns and villages throughout the country. Production per plant is copious, but the swamp areas to which they are restricted are of small total acreage. Positive skin reactions have been obtained with the pollen of cattail, presumably with both *T. latifolia* L. and *T. angustifolia* L., but in all the literature there is authentic record of only one case of clinical sensitiveness traceable to the pollen of this family. The pollen grains of *T. latifolia* are shed in clusters of four (tetrads), not singly as in *T. angustifolia.* Bulk pollen of either species may be bought for 50¢ to $1.00 per gram but there are few takers.

Composites and Related Families

The order Carduales, as monographed by Rydberg (15), consists of the chicory family (Cichoraceae), the ragweed family (Ambrosiaceae) and the thistle family (Carduaceae).[4] The ragweeds are all wind-pollinated, whereas all of the chicories and all ten thousand odd composites, except the genus *Artemisia* and a few unimportant closely related genera, are insect-pollinated. However, the pollens of the whole order, regardless of their method of distribution, are regarded by allergists as being very active allergenically, their toxic qualities having proved to be so similar that any species will usually give a positive skin reaction on a person who has been sensitized to any other. This is a very important point in the tasks of selecting tests and interpreting skin reactions.

Morphologically the pollen grains of all Carduales species are characterized by numerous more or less conspicuous surface spines, spicules or echinations. These are much larger on the entomophilous species, less conspicuous and in some genera quite indistinct on some of the anemophilous species.

Ragweed Family. Rydberg describes 111 species of Ambrosiaceae—annual and perennial herbs and shrubs, native and adventive or naturalized in North

[4] According to some botanical authorities the three families are one—all composites—the ragweeds and chicories being tribes in this great family.

America—which he classifies under 12 genera. The family name is borrowed from the pernicious annual weed, *Ambrosia elatior* L., so common in agricultural land throughout the eastern half of the United States. Other ragweeds are adapted to brackish tide flats, to fresh-water marshes, to sand dunes and sandy beaches, to dry prairies, deserts and rocky slopes. The flowers are small, clustered in inconspicuous green heads, the staminate heads usually arranged in long terminal spikes separate from the pistillate heads but on the same plant. Anthesis occurs usually from midsummer to late fall, rarely in spring and early summer. The usually inconspicuously three-pored (tricolpate) pollen grains are all of the spherical spiculated-echinate type, 14 to 26 microns in diameter, but usually 19 to 23 microns. Identification as to species is difficult except for the cockleburs (*Xanthium*) and prairie ragweeds (*Cyclachaena*). While the ragweeds do not enjoy a world-wide distribution comparable to that of the grasses, they are probably the most important group source of pollen allergens in the world. Certainly in the United States they are more important than all other hay fever plants taken together.

Short, or common, ragweed (*Ambrosia elatior* L.) is a native annual, freely branching, herb with gray-green, fernlike, twice pinnatifid leaves. The mature plants range in height with extremes of soil and climate from a few inches to ten feet. The original technical description of this species was written by Linnaeus in 1773. From pressed specimens of common ragweed which had been sent to him from America he selected two plants of extreme foliage variation and concluded that they represented separate species—plate 987 *A. elatior*, plate 988 *A. artemisiafolia*. Many botanists have now discarded the latter name. For reasons equally valid they also regard several other of the more recently described "species" as only interesting varieties of *A. elatior*. These include *A. diversifolia* (Piper) Rydb., *A. media* Rydb. and *A. longistylis* Nutt. of the West and *A. rugelii* Rydb., *A. glandulosa* Scheele and *A. monophylla* (Walt) Rydb. of the South. Wodehouse (25) remarks that the last variety might be worthy of specific recognition solely because of its peculiar habit of flowering in the spring (mid-April to June). Certainly there is no proved specificity in the reactions caused by the pollens of these varieties, so for the purpose of the allergist they are all short ragweed.

This public plant enemy No. 1 is one of the most common weed inhabitants of roadsides, fields, gardens, vacant lots and waste places throughout the eastern half of the United States and adjacent parts of Canada. The loose soil of grain fields offers the greatest opportunity for its propagation. Here it flourishes under ideal conditions, seldom hindered by sickle or plow, and annually maturing its untold tons of pollen after the grain has been harvested. Ragweed seeds are present everywhere, ready to spring up wherever the soil has been stirred and not preempted by other vegetation. I have counted 240 ragweed seedlings on a single square foot of fallow stubble land. Even so the weed is not difficult to control by shallow cultivation. It has a shallow root system and cannot hold its own against the native grasses when the land is left undisturbed for several seasons. Thus either less intensive or more intensive agricultural methods would greatly restrict its incidence.

Giant ragweed (*A. trifida* L.) is second in importance to short ragweed. In allergy literature it is referred to as tall ragweed, high ragweed, great ragweed and large ragweed. Farmers frequently call it horseweed and sometimes wild hemp. The plant is lusty, often growing in dense stands in rich moist lowlands, especially along ditches and in pure silt,

where it sometimes attains a height of 15 feet. Few persons recognize it as a ragweed because its large three- or five-parted leaves do not resemble the more finely divided leaves of short ragweed. The outstanding similarity in appearance of the two species is in the long spikes of green staminate heads which appear at the time of maturity. These spikes sometimes attain a length of six inches on short ragweed, 12 inches on giant ragweed.

FIG. 11. Special trailer used for transport of weeds from a distant area to the ripening laboratory. (*Courtesy of T. R. Stemen*).

Giant ragweed has not been overlooked by those taxonomists who delight in multiplication of species. However, the only one of several proposed divisions of *A. trifida* which is retained by Rydberg in his monograph on North American Flora (15) is western giant ragweed (*A. aptera* DC.), first described in 1836. It is said to be distinguished from *A. trifida* by a lack of wings on the petioles and by certain indistinct seed characteristics, and is supposed to be found only in the Southwest. Since the species is not accepted by many botanists there is no point to complicating the work of the allergists by raising unimportant varieties to the status of species, particularly when the pollen of the questionable species shows no morphologic or antigenic distinction.

Both short and giant ragweed reach their highest development in the central agricultural area of the United States but are widely distributed in tilled soil

from Maine to Florida and west to the Rocky Mountains. Since they are most abundant in the area of greatest population, they are recognized as of greater importance in allergy than all other ragweeds combined. Short ragweed thrives on less moisture than giant ragweed, so its range of distribution is somewhat greater. Very little giant ragweed is found east of the Connecticut River and none in the Florida peninsula. It seems to be absent also from Ontario except in the southernmost tip of the province.

In the northeastern quarter of the United States and the adjacent parts of Canada these ragweeds shed pollen in August and September. Giant ragweed comes to flower about ten days earlier than short ragweed and also reaches its climax of pollination earlier. Annoying quantities of pollen are usually found in the air between the 10th and 15th of August, with the climax of pollination near September 1, after which date production diminishes rapidly toward the end of the month. However, a heavy wind or close exposure in old weed patches can result in recurrence of symptoms even in October. In the southern States, particularly around the Gulf, the ragweed season stretches out two to four weeks longer than in the north, central and eastern States, with a climax as late as October 1 in the vicinity of Houston and Corpus Christi, Texas. In the southern half of Florida and the southern tip of Texas moderate air pollution may occur from May to November.

The spherical pollen grains of short and giant ragweed are very similar in microscopic appearance. When observed dry, in the polar position, they show three distinct constrictions in the extine. On expansion in an aqueous solution the three-lobed appearance of a grain disappears except for three small, equadistant, V-shaped notches around the equatorial periphery. These notches indicate the position of the three germinal pores which may be made visible by turning the pollen grain on its side. Giant ragweed pollen grains from lots of pollen grown in the northern States are slightly smaller than those of short ragweed (which average 20 microns in diameter), have somewhat coarser spines, but the differences are not great enough to make certain the identification of single specimens of ragweed pollen grains caught on atmospheric slides.

Enormous quantities of ragweed pollen have been collected and sold during the last 30 years, particularly when oral pollen treatment was in vogue. The present base price quoted by most collectors for either species is 30¢ per gram with liberal discounts for large bulk quantities. A few years ago quotations as low as 7¢ per gram were given on extra large orders, but it is impossible to see how anyone at present can produce ragweed pollen at a profit at less than 30¢ per gram.

Western ragweed (*A. psilostachya* DC.) is a coarse perennial species resembling short ragweed in size and leaf form. It is well named, since it replaces short ragweed in the more arid parts of the Great Basin, as well as in the intermountain States and the Southwest. Being a perennial it occasionally reaches maturity as early as May, but in no area or at any time is it a heavy producer unless given plenty of water. The pollen grains are slightly larger than those of short ragweed. Wodehouse notes that 50% of the grains have four pores. I cannot confirm this. Quoted at 50¢ to $1.25 per gram.

Southern ragweed (*A. bidentata* Michx.), also known as lance-leaved ragweed, is a locally abundant species in the Ozark region and surrounding areas, extending as far north as central Illinois and northern Missouri and as far south as northern Louisiana and northeastern Texas. This species with small lance-shaped leaves is more densely hairy and

somewhat more resinous than short ragweed to which it has only slight resemblance. Its typical habitat is the shallow limestone soil so frequently found in southwestern Missouri. In several counties of southern Illinois it replaces short ragweed in the wheat fields. The brief season of heavy pollination parallels that of short and giant ragweed. The pollen grains are so nearly identical to those of short ragweed that it has been impossible to study its actual or comparative aerial incidence by aerobiologic methods. The pollen is listed by collectors at 35¢ to $1.25 per gram.

Fully as important as western ragweed and southern ragweed is the large annual known to most allergists as burweed marsh elder (*Iva xanthifolia* Nutt.). It has also been referred to as tall poverty weed, horseweed, careless weed and prairie ragweed. The latter name seems ideal, even though neither the paniculate inflorescence nor the leaves resemble those of *Ambrosia*. "Burweed marsh elder" is not a suitable name for this dominant farm land weed of the western and northwestern parts of the Great Basin. It is not a marsh plant in any sense. Even though the leaves do slightly resemble those of cocklebur, as suggested by both the above botanical name and the popular designation "burweed", they are more like the leaves of sunflower in size and shape. Most modern botanists agree that it should not be classified with the marsh elders (*Iva*). Allergists would not be inconvenienced by adopting the name *Cyclachaena xanthifolia* (Nutt.) Fresen. This ragweed reaches maturity at the same time as giant and short ragweed and produces abundantly. The quality of the pollen has not been thoroughly investigated, but from present evidence it seems to be less active than that of short ragweed. Morphologically the pollen grains are easily distinguished from those of other ragweeds in its geographic range because of the three long furrows accompanying the three germinal pores. When dry the grains resemble a grain of wheat and when moist have deeper equatorial notches than the grains of any of the other ragweeds. The pollen is easily collected, but for some reason is priced higher than that of the other common ragweed species—50¢ to $2.00 per gram. Three other species of *Cyclachaena* are of sparse local distribution in the southwestern States and northern Mexico. None of these is mentioned in allergy literature.

The marsh elders of the United States are all of local or minor allergic importance only. The species differ greatly in appearance, habit and habitat. Rough marsh elder (*I. ciliata* Willd.), the most important species, is a rough annual found in marshes and very moist soil from southeastern Nebraska and western Illinois southward through the Ozarks to the Louisiana and Texas coasts (*I. caudata* Small seems to be only a spindly variety of *I. ciliata*). It reaches its greatest development in the Mississippi delta region of Louisiana where it ranks with short ragweed and giant ragweed in overall pollen production. It is also common in the alluvial soil of the Texas coast land. Like *Cyclachaena*, its flowering spikes contain both staminate and pistillate heads. Neither the leaves, spikes nor shape of the plant suggests any relationship to common ragweed.

In central and eastern Texas and adjacent parts of Oklahoma, Arkansas and Louisiana, narrow-leaved marsh elder (*I. angustifolia* Nutt.), a prairie species superficially resembling short ragweed, is fairly abundant and productive. Another dry land species with linear leaves (*I. microcephalata* Nutt.) is found in the pine barrens of southeastern Georgia and northern Florida. *I. frutescens* L., a tall shrub resembling *Baccharis*, grows only in salt marshes along the Atlantic and Gulf coasts. Whether *I. oraria* Bartlett

is a small variety of *I. frutescens* or a separate species is not entirely clear. Production of pollen is meager. In the western parts of the Great Basin and in the Rocky Mountain States poverty weed (*I. axillaris* Pursh.), a dwarf, is occasionally found in alkaline fields and waste places. Since it has a woody creeping rootstock it is able to come to bloom in June and July, but its atmospheric contribution at that season is negligible. The pollen grains of the *Iva* genus are so similar to those of *Ambrosia* that it is impossible to assess with certainty, by means of air tests, the part they play in inhalant allergy. Pollens of only two species are offered at present by collectors—rough marsh elder at $1.50 per gram and poverty weed at $2.00, but *I. angustifolia* pollen is collected and used locally by Texas allergists.

The false ragweeds (*Franseria*), mostly perennial herbs of the West and Southwest, are as a genus easily differentiated from *Ambrosia* by their spiny seeds. Only two of the 39 North American species are frequently mentioned in allergy literature. Bur, or false, ragweed (*F. acanthicarpa* (Hook.) Coville), with seeds resembling sandburs (*Cenchrus*), is a coarse locally abundant annual in tilled soil from western Kansas throughout the intermountain States and the Southwest. It is frequently mentioned in pollen surveys of southern California, but its acreage is too limited in most areas for it to cause significant upper air contamination. Locally it is rated as important. Slender false ragweed (*F. tenuifolia* Harv. & Gray) of the Southwest (Texas to California and New Mexico) is a small perennial with leaves much like short ragweed. It is most abundant in southwest Texas where it largely replaces short ragweed and is responsible for a large part of the airborne ragweed pollen in August, September and October. In Arizona it has been reported to flower occasionally as early as May.

Franseria discolor Nutt. and *F. tomentosa* A. Gray are frequent but nowhere abundant in the lightly populated prairies east of the Rocky Mountains. Beach bur (*F. bipinnatifida* Nutt.) and three very similar decumbent sea beach species (*F. vilosa* (Eastw.) Rydb., *F. lessingii* Meyen & Walt., *F. chamissonis* Less.) grow in occasional dense clumps or mats along the shore from Vancouver to San Diego. They are certainly a potential source of trouble if one were closely exposed to them, but atmospheric ragweed pollen records at Port Angeles and Seattle, Washington, as well as at San Francisco, Los Angeles and San Diego, California, prove that they are entirely negligible as far as general upper air contamination is concerned.

Most interesting as to habit of growth and pollination are the two small desert species, rabbit bush (*F. deltoidea* Torr.) and bush sandbur (*F. dumosa* A. Gray) together with the somewhat larger canyon ragweed (*F. ambrosioides* Cav.), all of Arizona and southern California. These shrubs shed their pollen in March and April instead of late summer and fall. The latter is also noteworthy for its extra large burs which resemble cocklebur in size and shape. Of the three, *F. deltoidea* is said to be the most important contributor to the spring ragweed hay fever season which in some parts of the far Southwest is more of a hazard than the fall ragweed.

The pollen grains of slender false ragweed are very much like those of short ragweed except for the numerous variable oversized grains and a preponderance of grains, both large and small, having four or more pores. All other *Franseria* species have short to almost invisible spines. By this they can be differentiated from *Ambrosia* pollens in areas where the latter are found. All are essentially tricolpate and uniform in size within the species, varying only slightly in size from that of short and giant ragweed.

There is little demand and no local need for false ragweed pollens in the central and eastern States. Collection is comparatively difficult because of distances which must be traveled in collecting different species, so prices are relatively high—$1.50 to $3.00 per gram. every part of the United States. The pollen is fully as active as that of any of the other ragweed species, if not more so, but it is produced in relatively small amounts, making collection quite tedious. Of the 21 North American species recognized by Millspaugh and Sherff (13),

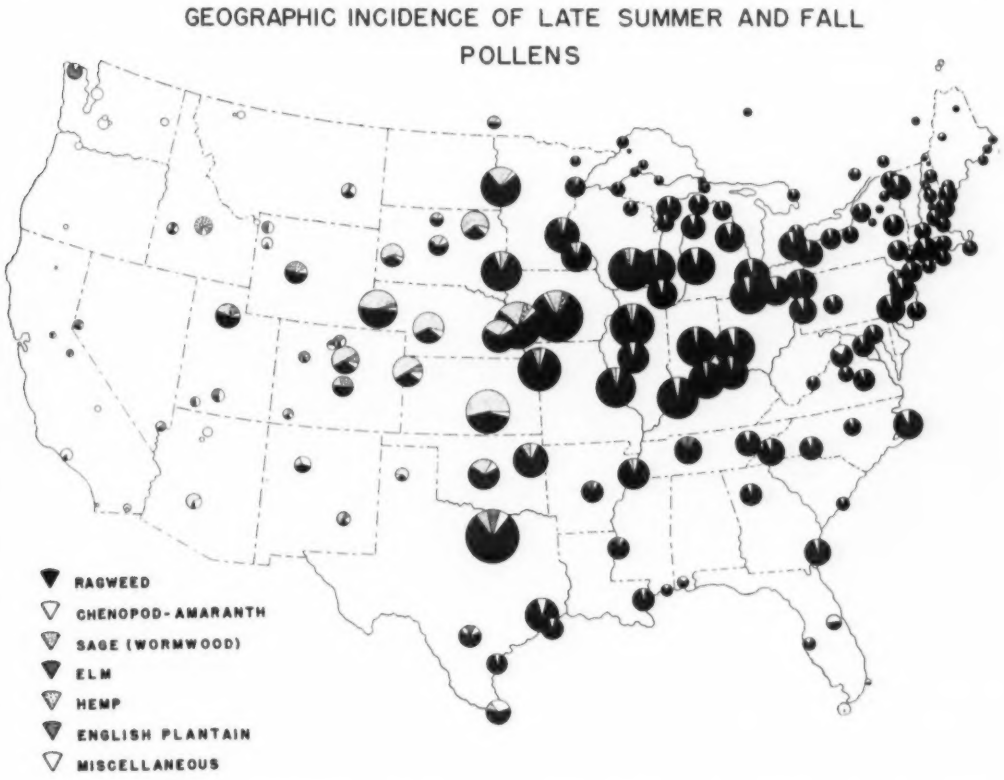


FIG. 12. Seasonal atmospheric incidence of air-borne pollens of late summer and fall, shown in comparative seasonal totals and local proportions for typical localities. Data compiled by Oren C. Durham from studies made by members of the Pollen Survey Committee of the American Academy of Allergy in collaboration with several city and state boards of health, U. S. Weather Bureau and Canadian Meteorological Service. Revised January, 1950.

All species mentioned in the above paragraph are included in current lists.

The cocklebur (*Xanthium*) are odd members of the ragweed family, with foliage and fruits so different from those of other ragweeds as to leave doubts in the mind of anyone except a taxonomist about their classification. These pernicious agricultural weeds are common in cultivated fields and gardens in almost only spiny cocklebur (*S. spinosum* L.) has noticeable superficial differences, and as far as the allergists are concerned little attention is paid to specific names. The pollen grains are decidedly larger than those of the other ragweeds, and the spicules are very small, as in most forms of *Franseria*. Throughout the central agricultural States no local annual atmospheric pollen surveys have revealed

the proportion of cocklebur pollen as compared with that of other ragweed pollen of more than 2%. Nevertheless, there is a steady demand for the pollen which is offered by collectors under the general designation of *Xanthium* spp. or as *X. commune* Britt. or *X. canadense* Mill. The price is $1.25 to $2.00 per gram. Spiny cocklebur pollen extract is marketed by one western pharmaceutical manufacturer, but the dried pollen is not offered at present.

Seven other ragweed genera of the lightly populated districts of the Southwest and Mexico are represented by some 16 species in areas where the population is sparse. These have not been exploited in allergy literature except for jecote (*Hymenoclea monogyra* T. & G.) and burrobrush (*H. salsola* T. & G.). The former is a large shrub, three to twelve feet high. Pollens of both are offered by one southwestern collector at $2.00 per gram.

Sagebrushes. Names are seldom in such multiplicity nor species criteria in such apparent ferment as in the genus *Artemisia*. Popular general designations of the numerous forms include sagebrush, sagewort, sage, mugwort, wormwood and cudweed, with no end of descriptive handles. As for botanical names it is sufficient to give two examples showing extreme variance in expert opinion. Rydberg, in his monograph on North American Flora (16), lists 120 species, while Hall and Clements (9) allow only 29, regarding all the numerous forms as varieties of these 29 species. For the purposes of the allergists a further condensation, if possible, would be warmly welcomed, since all clinical work done so far has failed to show any difference in the allergenic character of the pollens of different varieties or species. Moreover, their allergenic character is so very similar to that of the ragweeds that differentiation can hardly be made. Since the sagebrushes flower at about the same season as the ragweeds, skin testing is of very little help in segregating specific sagebrush hay fever cases outside of the exceptional western areas where ragweeds are absent and *Artemisia* abundant. In spite of notations by some authors about certain species shedding "enormous quantities of pollen", the best yields of any of them do not begin to compare with that of the ragweeds, as proved by local atmospheric contamination figures from 50 western studies.

True sagebrush (*A. tridentata* Nutt.), a widely distributed shrub of the Rocky Mountain States, is typical, except for size, of the genus and probably the source of more wind-borne pollen than any other western form of *Artemisia*. The plant reaches a maximum height of 15 feet under favorable conditions and is well known for its pungent odor and its small three-toothed canescent leaves. The highest reported atmospheric concentration of *Artemisia* pollen (accumulated annual total) has been recorded at Sun Valley, Idaho, where *A. tridentata* is the dominant plant for miles in every direction.

Pasture sage (*A. frigida* Willd.), a low growing canescent species, is common in the plains just east of the Rocky Mountains. A fairly high atmospheric count in Colorado Springs can be traced to this source. Sand sagebrush (*A. filifolia* Torr.), a feathery three-foot shrub, is typical of the dust bowl country of western Nebraska and eastern Colorado through the Panhandle of Texas. Significant counts of pollen from this source have been recorded at one town in western Kansas. In California the only proved actively producing species is *A. californica* Less. of the coast ranges between Los Angeles and San Diego.

Of unusual interest is the only annual species, annual sage (*A. annua* L.), a tall, green, aromatic weed found in abundance in many mid-southern cities but so unusually abundant in Nashville,

Tennessee, as to vie with ragweed as a vacant lot inhabitant. Even here with extremely close contacts of allergic persons to the moderate amount of airborne pollen it is difficult to prove that it adds anything to the suffering of the ragweed victims of the area.

Pollen grains of the sagebrushes are tricolpate with long deep furrows when dry (collapsed) and spheroidal when expanded. The size in most cases is about the same as that of the common ragweeds but the extine is much heavier, the pores weaker, allowing slight extrusion of the intine, and the spines extremely small or absent. Exact identification of the numerous species is impossible. Bulk of pollen of some 15 *Artemisia* species is available at prices ranging from $1.00 to $2.50 per gram.

FIG. 13. Wheal reactions elicited on a pollen-sensitive allergic by application of scratch tests of moist pollen or pollen extracts of various species.

Entomophilous Composites. If all of the composites (including the Cichora-

ceae) other than the sagebrushes could be dismissed from serious consideration as allergens with the statement that their pollens are never found in the air and therefore can never cause inhalant allergy, these plants would still remain of academic interest to allergists and allergics because their pollens have strong antigenic activity, paralleling that of the closely related ragweeds. Actually the pollens of some strictly insect-pollinated composites can, under special situations, be contacted in small but significant amounts. During the late fall in several southern States small amounts of pollen of dog fennel (*Eupatorium capillifolium* (Lam.) Small) are found in the air. Florists and gardeners sometimes come in very close contact with various composites. There is always the possibility that such exposure may result in specific sensitization or aggravation of ragweed symptoms. In addition, the doctor must reckon with the goldenrod tradition and similar folk notions about allergy. So the demand continues for numerous pollens which are extremely improbable basic causes of allergy. Even though they are often difficult to collect in quantity sufficient for the purposes of allergy, current collectors' lists offer one to several species of the following genera at prices ranging from $1.50 to $3.50 per gram: *Achillea*, *Anthemis*, *Aster*, *Baccharis*, *Callistephus*, *Chrysothamnus*, *Chrysanthemum*, *Coreopsis*, *Cosmos*, *Dahlia*, *Erigeron*, *Eupatorium*, *Gaillardia*, *Helianthus*, *Rudbeckia*, *Scabiosa*, *Solidago*, *Tagetes*, *Taraxacum* and *Zinnia*.

Chenopods and Amaranths

The chenopod, or goosefoot, family (Chenopodiaceae) and the amaranth, or pigweed family (Amaranthaceae) are the two outstanding members of the order Chenopodiales. The former is said to be made up of 223 species, the latter of 162. As with the Carduales, allergic interest is focused on the order because of the very similar antigenic character of the pollens of all species in the two families (17). All are wind-borne, save *Celosia* and *Gomphrena*, and all have pollen grains of the same "golfball" type. Aerial distribution of toxic amounts of this type of pollen is confined almost entirely to the area west of the 95th meridian—from eastern Kansas and western Minnesota westward.

Russian thistle (*Salsola pestifer* A. Nels., for purposes of allergy not distinguished from *S. kali* L.), though not nearly so productive as several of the Amaranthaceae, is easily the most important hay fever plant in the whole order because of the extreme toxicity of its pollen. An agricultural pest from the Old World, it is now widely distributed and well established throughout the western part of the Mississippi Basin and in the Rocky Mountain and intermountain States, where it thrives in dry alkaline or sandy soil almost as well as in loam. In many localities it is the principal allergic offender. The plant is an annual, globular in general outline with fine, thread-like leaves which are reduced to sharp scales as they mature. After flowering, the whole plant frequently breaks off at the ground and rolls with the wind, hence the common designation "tumbleweed". Its small, inconspicuous, perfect flowers reach anthesis in most areas in early July—about a month ahead of the ragweeds—and continue to contaminate the air during most of the ragweed season. The heaviest atmospheric concentrations of record have been found at Moorhead, Minnesota (opposite Fargo, North Dakota), in the Red River Valley. Effective concentrations are also encountered locally throughout its whole range. The spherical pollen grains average 26 microns in diameter, with pores larger and farther apart than the average for the genus, making them easily identified in aerobiologic work. The difficulty involved in

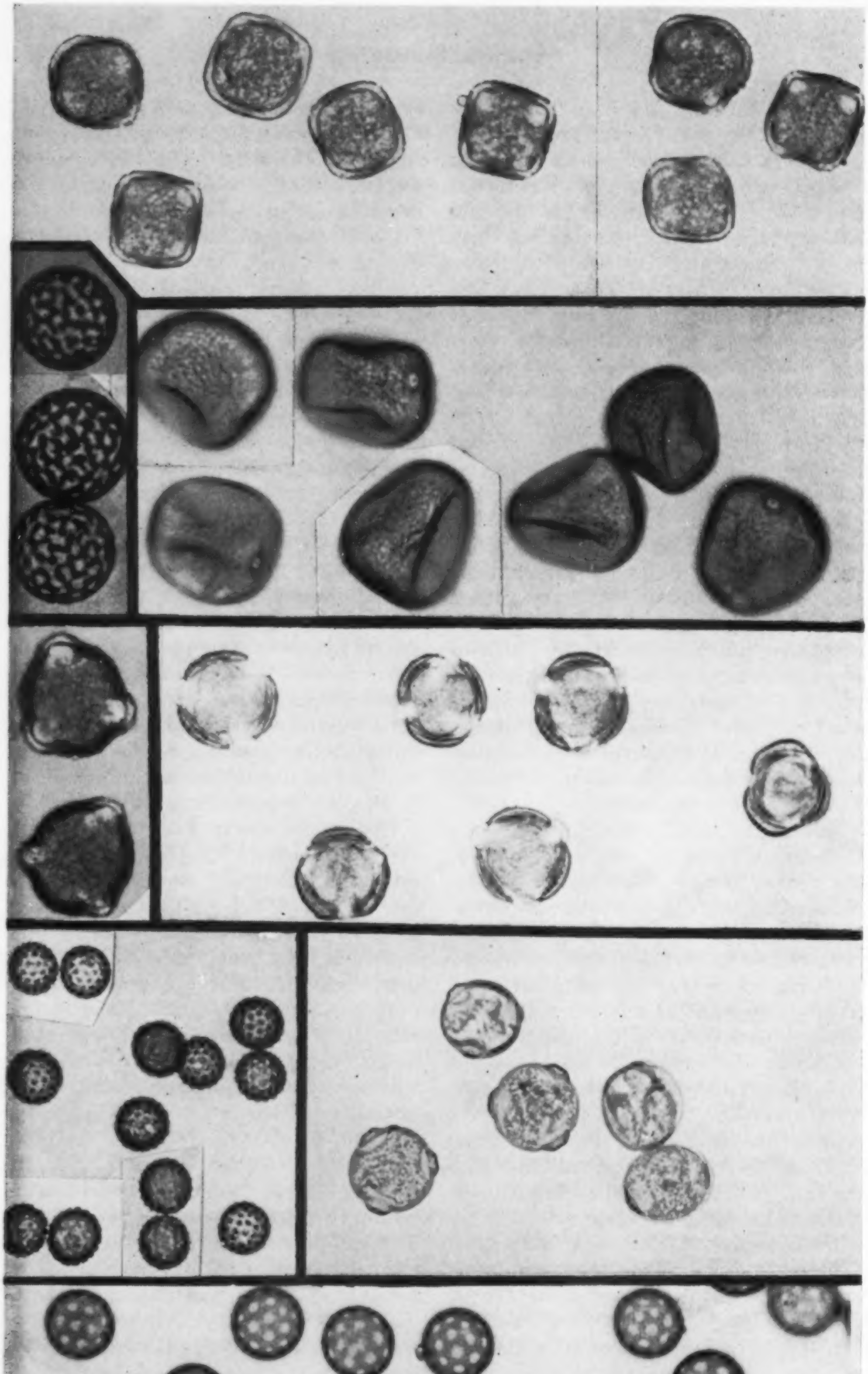
collecting the pollen is reflected in the price of $2.00 to $2.75 per gram.

Mexican fireweed, or kochia (*Kochia scoparia* Roth), also a globular annual and a European import, has in the last half century become the dominant weed of farm lands and city wastes in many localities in Nebraska, the Dakotas and eastern Colorado. From this center it has spread in all directions. More vigorous than Russian thistle, it disputes territory not only with Russian thistle but even with the ragweeds, and has in the last two or three decades invaded the large cities of the central States as far east as Detroit. Its productivity is greater than that of Russian thistle, but the range of dispersal of pollen is restricted by the larger, heavier pollen grains. There is still doubt about the allergenic quality of the pollen. It will, of course, interreact with the pollen of other goosefoots when used in skin testing, but in localities where kochia is abundant and Russian thistle absent there is little, if any, evidence of clinical sensitiveness to kochia pollen. Priced at $1.00 to $2.00 per gram.

More than half of the chenopods are included in the saltbush genus, *Atriplex*. They are divided roughly into monoecious annuals, most of which are partial to alkaline soils of the West, and dioecious canescent shrubs of the dry deserts. *A. wrightii* Wats. of the Southwest, locally important as a cause of inhalant allergy, is typical of the former, and shadscale (*A. canescens* Nutt.) of the Great Basin and Southwest, of the latter. As a group the species of *Atriplex*, like most chenopods, come to flower from early to midsummer and continue into the fall. Their output of pollen is moderate in amount; its allergenic activity is not questioned. Certain identification of pollen grains—even of the genus, much less the species—is in most cases difficult or impossible. Of the 130 North American species, the pollens of only about a dozen are at present used by allergists. Collectors could probably produce scores of others on order. The following are priced at $1.75 to $2.00 per gram: *A. argentia* Nutt., *A. bracteosa* (Durand & Hilgard) Wats., *A. hastata* L., *A. brewerii* Wats., *A. polycarpa* (Torr.) Wats., *A. rosea* L., *A. canescens* Nutt., *A. lentiformis* Wats., *A. confertifolia* (Torr.) Wats., *A. elegans* (Moq.) Dietr., and *A. wrightii* Wats.

In the *Chenopodium* genus none of the 50 odd species is outstanding in production of pollen or in the quality of its allergenic content. The pollens cause clear-cut reactions when used in skin test but have not been proved to be of real clinical importance. Lamb's quarters (*C. album* L.), for example, and several closely related species are widely distributed throughout the central and eastern States—very common garden and field weeds. Skin reactions are sometimes obtained with their pollens on residents of the central and eastern States, but these persons do not have symptoms during midsummer when the weeds are in flower. Nevertheless, the pollens of a few species are in moderate demand: Jerusalem oak (*C. botryss*), lamb's quarters (*C. album* L.) and Mexican tea (*C. ambrosioides* L.). Prices range from $1.40 to $2.00 per gram.

Two of the Chenopodiaceae are widely used for food, spinach (*Spinacia oleraceae* L.) and beet (*Beta vulgaris* L.). Sugar beets are grown as a field crop in many parts of the country, but only where they are allowed to remain in the ground until the second year, as in the seed fields of Arizona, does flowering take place. Pollen production is extremely heavy, and allergic sensitization within the range of dispersal is common. The pollen grains (18 and 19 microns) are easily recognized by their small size. Demand for the pollen is only local. The price is $2.00 per gram. Pollens of the following Chenopodiaceae are of



doubtful or very local importance but may be purchased at the prices noted: greasewood (*Sarcobatus vermiculatus* Torr.), $1.75; glasswort (*Salicornia ambigua* Michx.), $3.50; winter fat (*Eurotia lanata* Moq.), $1.75; burroweed (*Allenrolfea occidentalis* Ktz.), $3.50; alkali blite (*Sueda moquina* Greene), $2.75; and "*Bassia hyssopifolia*", $2.00.

For practical purposes of allergy the pigweeds (Amaranthaceae) may be divided into two groups on the basis of their inflorescence. The monoecious species are of little consequence because of either low productivity or low toxicity of the pollen. The dioecious species are abundant producers and atmospheric contaminators, even rivaling ragweed, but are in all cases of regional or restricted distribution. *Amaranthus* and *Acnida* are the only two genera of interest to allergists. All species of these two genera are annual weeds growing only in tilled soil. Palmer's amaranth, otherwise known as "careless weed" (*Amaranthus palmeri* Wats.), is by all odds the most important dioecious pigweed. A lusty plant attaining a height of five feet, with slender terminal spikes resembling those of *Acnida*, it is one of the most important sources of active pollen in the Southwest—Texas to southern California. Torrey's amaranth (*Amaranthus torreyi* (A. Gray) Benth.), common in southern Kansas and Oklahoma, likewise produces copiously but for some reason has received little attention from allergists or collectors. Western water hemp (*Acnida tamariscina* (Nutt.) Wood) is a very common tall cornfield weed in moist lands of Iowa, Kansas, Nebraska, Missouri and Oklahoma. Its production is particularly heavy, but little evidence has been produced to incriminate the pollen as an active sensitizer. *A. cannabina*, a salt water marsh species common in Florida, has not been given adequate study. Pollen of the following pigweeds is available at prices ranging from $1.50 to $2.00 per gram: rough, or redroot, pigweed (*Amaranthus retroflexus* L.), slender pigweed (*A. hybridus* L.), spiny amaranth (*A. spinosus* L.) and western water hemp (*Acnida tamariscina* (Nutt.) Wood). It is particularly unfortunate that tumbling pigweed (*Amaranthus graecizans* L.) was ever mentioned in allergy literature because its productive ability is too small for consideration. Collectors have a very difficult task in supplying the pollen at any price. It is listed at $3.50.

Miscellaneous Wind-pollinated Herbs

Nettle Relatives. The hemp family (Cannabinaceae) and the nettle family (Urticaceae) are regarded as close botanical relatives and not too far removed from the elms, mulberries, paper mulberry, hackberries and osage orange. Allergists have often mentioned the possibility of group allergenic qualities in the pollens of the four families involved, but so far very little work has been done on the problem. As far as the pollen grains are concerned those of elm and hackberry are quite unlike those of other genera in the group.

Hemp (*Cannabis sativa* L.) is a tall dioecious annual escaped from cultivation and lately become notorious as a source of the drug marihuana. It grows in moist tilled or friable soil where one would expect to see giant ragweed or water hemp. It is particularly abundant

FIG. 14. Photomicrographs of pollen of the following:

Ash ×500
Western water hemp ×550 Timothy ×500
Red oak ×500 Sagebrush ×500
Short ragweed ×350 Hemp ×500
Russian thistle ×400

in western Iowa, eastern Nebraska and the adjacent corners of Kansas and Missouri in spite of anti-narcotic laws. Like most dioecious species it is a prolific pollen producer. The period of anthesis is from late July to early September. The highest atmospheric concentration of record is from Omaha, Nebraska. The pollen is regarded by local allergists as being more toxic than that of ragweed, and far more so than any of its botanical relatives. The pollen grains are flattened spheres, irregularly shrunken when dry, 25 microns in diameter, smooth, tricolpate with thickened subexinous collars (aspides) around each pore. They are easily identified on atmospheric test slides except for occasional confusion with grains of hop (*Humulus lupulus* L.) pollen. Collection is not difficult, but, since it has been illegal for anyone to possess or buy or sell the pollen without special narcotic permit, no collector now offers it for sale.

Cultivated hop (*H. lupulus*) and the wild Japanese hop (*H. japonicus* Sieb. and Zucc.), both rough perennial vines with dioecious flowers, are potential hay fever plants, but the allergenic qualities of the former have not been assayed, even in the areas of the Pacific Northwest where hops are grown commercially, and the latter seems to be nowhere abundant enough to cause trouble. Pollen grains of both species are very similar to those of hemp. Commercial quantities are available of the cultivated species only, at $1.00 per gram.

The stinging nettles (*Urtica dioica* L. and *U. gracilis* Ait.), perennial weeds of the central and eastern States, produce moderate amounts of wind-borne pollen easily identified because of having only two pores and by its very small size, 11 to 15 microns. On atmospheric slides it would be confused with the pollen of paper mulberry except that the seasons of anthesis do not coincide. Its role of allergy has not been assessed. The pollen of *U. gracilis* is listed at $1.45 per gram.

Buckwheat Family. The only common wind-pollinated genera of the Polygonaceae are the docks (*Rumex*), and rhubarb (*Rheum rhaponticum* L.). Of the docks the only freely producing species is the low-growing dioecious red sorrel (*R. acetosella* L.) of the prairies and pastures in almost all parts of North America. All docks flower in early summer, their season coinciding in most places with that of the grasses. Spherical pollen grains of red sorrel (22 microns) have thin comparatively smooth extine with four long shallow grooves and four germinal pores. They can scarcely be distinguished from the other common docks. Demand for any of the dock pollens is light. *R. acetosella* is priced at 60¢ to 75¢ per gram; other species as follows are higher—$1.10 to $1.75 per gram: *R. obtusifolia* L., *R. crispus* L., *R. altisimus* Wood, *R. mexicanus* Meisn., *R. hymenosepalis*.

Plantain Family. English plantain (*Plantago lanceolata* L.), a well-known weed of lawns and waste places, is widely distributed throughout most of the United States but rarely locally abundant. Our highest atmospheric counts come from the Pacific Northwest (western Washington and western Oregon). Production per plant is liberal and, since the weed is frequently allowed to flower on lawns, close exposure is possible. The pollen is moderately toxic, causing a few cases of specific sensitiveness along the eastern seaboard and a greater number in the Pacific Northwest. Broad-leaved plantain, both *P. major* L. and *P. rugelii* Dene., should be written off the list because of their very low productivity. English plantain pollen grains are spherical with four to 14 small round germinal pores somewhat irregularly placed. The size of the grains varies greatly, even in samples from a single plant—according to Wodehouse (25), 16 to 40 microns.

P. lanceolata is priced at 40¢ to 60¢ per gram, *P. major* $2.00.

Miscellaneous Entomophilous Species

Fabaceae. Of all families of entomophilous plants none is more certainly adapted to insect pollination than the Fabaceae. Yet collectors must devise means for drying, thrashing and sifting the leguminous hay plants in order to satisfy the demands of those who insist that hay dust causes their attacks of asthma. Of course, most hay dust contains many grass pollen grains as well as the allergenic spores of the common soil fungi, but the clover blossoms are more conspicuous and are therefore the target of accusation. No collector pretends to deliver pure pollen of alfalfa (*Medicago sativa* L.) or of the clovers (*Melilotus alba* Desv., *Trifolium repens* L. and *T. pratense* L.). Separation of the finer particles of inflorescence from the pollen is impracticable, but the purchaser understands the difficulty and pays $3.50 to $5.00 per gram for the "adulterated" pollen. Even Scotch broom (*Cytisus scoparius* (L.) Link) is available at $3.50.

Roses, etc. The "rose fever" tradition is as old as the goldenrod idea and, like it, will probably never die, in spite of the well-authenticated instance of violent hay fever caused by the sight of an artificial rose ("*Rosa papyrifera*", perhaps). Pollen is entirely lacking on most cultivated varieties and that of the wild species is never found in the air. The occasional demand is supplied by pollen of *Rosa rugosa* and other species at $3.00 per gram.

The list of plants from which pollens could be collected is endless—plants from the garden, greenhouse and farm, as well as those of waste places. Once a plant is inadvertently mentioned in allergy literature the collectors will do their best to fill orders and thereafter give the item a place in the "miscellaneous" section of their catalog. Random examples include "*Petunia hybrida*—$2.00, snow-on-the-mountain, *Euphorbia variegata*—$3.00, and squash, *Cucurbita pepo*—$1.50."

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Utilization Abstract

Legume Mucilages. "Prior to World War II the mucilage from seed of the Carob tree, *Ceratonia Siliqua*, was used extensively in the paper, textile, food, and some other industries under the name 'locust bean gum'. Supplies of this seed come from countries around the Mediterranean Sea and were greatly reduced early in the war. In a search for mucilages similar to carob mucilage, seeds from 163 species of legumes were studied from 1941 to 1943. Three-quarters of these were found to contain mucilage-yielding endosperms. . . . The amount of endosperm in seeds of different species of legumes varied from zero to over 50% of the seed and the percentage of soluble mucilage in some cases amounted to over 40% of the seed. . . . Although other naturally occurring mucilages were examined, none had the properties of carob mucilage. . . . Since the physical properties of all these endosperm mucilages resemble closely those of carob mucilage, any one of them might be used in place of carob mucilage if it could be manufactured at a suitable cost. Seeds of the legume guar [*Cyamopsis tetragonolobus*] yield over 40% mucilage which can be milled from the seed. Since this crop adds nitrogen to the soil and can be grown and harvested mechanically, guar seed appear to be a promising industrial source of this mucilage. Tara seed [*Caesalpinia tinctoria*] occur in Lima, Peru, as a by-product of exportation of tara pods for use in tanning. These, together with a number of other leguminous seeds from which endosperm mucilages can be milled, form possible industrial sources of these mucilages. Beginning in 1943 the growth of guar in the southwestern United States was encouraged by General Mills, Inc., of Minneapolis, Minn. Shortly afterward guar mucilage was placed on the market by this company".

A review of the chemical literature on leguminous mucilages is given in this article as well as the results of original investigations on the 163 species studied. One hundred twenty of them in 39 genera were found to contain endosperm mucilages; 40 species in 29 other genera (only *Acacia* appears in both lists) gave no endosperm mucilages. (Ernest Anderson, *Ind. & Eng. Chem. 41: 2287. 1949*).

Guayule—*An American Source of Rubber*

Over three million acres of marginal farm land in the United States are capable of producing guayule rubber. Use of existing strains on these lands would produce 200,000 long tons of natural rubber per year. Plant breeding and process research could raise this to at least 300,000 long tons, or about half of our annual consumption of natural rubber.

KENNETH W. TAYLOR [1]

Introduction

In the 350 odd years that have elapsed since discovery of the New World by European explorers, tradesmen have capitalized on the virtues of new plants from the Americas. Potatoes, tomatoes, maize and tobacco are only a few of them. There are many others that have found their way into the trade marts of the world, but most of them have come from deep fertile soils where the rainfall is high and vegetation lush. The bleak arid semi-desert areas have contributed little by way of botanicals, but they hold a whole host of promises for interesting and useful plant products. To be sure, the century plants have provided cordage and fiery tequila, both of which have been used since the time of the conquistadors. Cochineal, a sort of botanical by-product now used but little, provided a valuable dye for many decades. There are others, such as the strange peyote and the ancient Indian medicinals, whose usefulness has largely been overlooked by the white man. And there are still other plants whose usefulness and value are known, but which have had their ups and downs because of international politics, trade relations and other man-made hindrances. Guayule [2] is such a plant.

Species. Guayule (*Parthenium argentatum* Gray) is one of the Compositae, that vast family of plants whose representatives are found throughout the world. The genus *Parthenium*, including at least 12 distinct species, is strictly a western hemisphere member. The various species range in size from the little *P. hysterophorus* L., which may be found adventively pushing its scant inches up through the less frequented sidewalks of Boston, to the giant of the clan, *P. stramonium* Greene, which raises its woody branches 18 to 25 feet into the air of its native home in northwestern Mexico. The smallest of them all is *P. alpinum* in the mountains of Colorado.

Guayule, a plant of the Chihuahuan desert areas of Texas and Mexico, is important because at this writing it is the most promising rubber producer that can be grown successfully in continental United States. This does not except the "saghyzes", the Russian dandelions, which can be grown here and which do produce an excellent rubber, but whose per acre yield is niggardly.

History. Unlike the Russian dandelions, however, guayule is no newcomer to the American scene. Lloyd (3), from whose classic work the following historical account is largely taken, credits Dr.

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[2] Webster gives the preferred pronunciation as gwä-yōō′-lā. Usage, however, builds the language, and the accepted pronunciation is wī-ōō′-lā.

J. M. Bigelow as the first white man to discover guayule. While attached to the Mexican Boundary Survey in 1852 he collected specimens of the plant "near Escondido Creek, Texas". His type specimen was sent to Harvard University where it became the basis for Professor Asa Gray's original description.

Commercial use of guayule was delayed many years after Bigelow's discovery. As a matter of fact, it is doubtful that he was aware the plant had any rubber in it. The native Indians, however, had used guayule in the production of rubber balls for centuries. The rubber for these playthings was obtained by communal mastication of the bark. The practice has been pretty well authenticated to the middle of the eighteenth century and was probably common hundreds of years before that.

Rubber production was not the only use to which guayule was put. It has a high resin content which makes it burn with a fierce hot flame. The Mexicans were quick to take advantage of this fact and used it in crude adobe smelters, wherever it was available, as a source of fuel for recovering silver from its ores. When its value as a rubber producer was established the practice of using it as a fuel was quickly stopped.

Early Commercial Development. Twenty-four years after Bigelow first collected the scraggly bush along the Mexican border, guayule rubber was seen in the United States. The Mexican Government sent an exhibit of their product from Durango to the Centennial Exposition in Philadelphia, 1876.

Commercial production of guayule rubber was slow in materializing. Some small use was made of it in New Jersey in 1888, and in that year the English began to show an interest in the product. At about the same time one Herr Juan Fritz employed a group of peons to chew out a quantity of rubber for testing by German chemists. These gentlemen were not overly impressed with the product they received; however, they established the first field laboratory at San Luis Potosi about 1900. Researches of this laboratory led to the construction of a factory and the production of some rubber at Jimulco in 1902 by Adolph Marx.

American experimentation began in that year, and Wm. A. Lawrence devised a successful mechanical process for the extraction of crude rubber from the shrub. Two years later small lots of rubber were shipped to the United States where most of it was used by the Manhattan Rubber Company. The product was well received and its use led to the erection of a large factory at Torreon. Lawrence's mechanical extraction process was used exclusively in this factory and was so successful that this method superseded all others. Success at the Torreon plant led to the rapid establishment of factories at various other points in Mexico where there was enough shrub to justify the financial outlay. Demand for guayule crudes became sufficiently strong for risk captal to carry out operations at a factory built at Marathon, Texas, in the center of the Big Bend country. From that time on, guayule business boomed, and in 1911 thirty million American dollars were reputedly invested in guayule in Mexico.

In 1909 Mexico shipped 9,542 long tons of guayule rubber to the United States as compared to 5,556 long tons of Hevea rubber imported from all other sources (4). Guayule was for the next several years a strong competitor of all grades of Hevea or plantation rubber until quantities of cheap plantation rubber came on the market. It is also true that the quality and cleanliness of plantation rubber improved, while guayule still came out of the shipping boxes in about the same shape it always had.

Growth and Culture

Natural Distribution. Guayule in nature occupies a rather wide geographic range, but is locally restricted within that range by climatic and edaphic factors.

Grossly it is found in an area extending from Presidio, Brewster and Pecos counties in Texas on the north, south and west to a point near the northern boundary of the State of Durango, then southeast to the neighborhood of the city of San Luis Potosi, where it ranges somewhat west of north until the Texas border is crossed again. Probably less than ten percent of the 130,000 square miles in this area ever bore guayule, and over much of this ten percent the stands have been thin and sparse. Rather frequently guayule has been erroneously reported from New Mexico and Arizona, and during the last war specimens of plants were repeatedly received from points as far away as California and Nevada. Never did these specimens prove to be guayule. Usually they turned out to be sage, rabbit brush or some other desert shrub bearing only superficial resemblances to guayule.

Habitat. Most of the feral guayule grows at altitudes between 2,000 and 6,000 feet above sea level. Generally speaking, the wild plants are found on limestone ridges where the soil is scant and where drainage is largely surface. Gravel is common, but it consists of limey fragments interspersed throughout the loam so that it is not a true drouthy gravel. Annual rainfall ranges from 10 to 15 inches per year with most of the effective rain falling in the summer months. The relative humidity is surprisingly high for a desert area, and this peculiarity makes the limited rainfall more effective than would seem possible. This peculiar combination of requirements restricts guayule to low hills and ridges; in fact, the best stands have been found on foot slopes bordering the playas (3, 8). Throughout its range guayule is found where temperatures are quite uniform. Daytime maxima rarely exceed 95° F. and minimum temperatures are seldom below 0° F.

Mexican Utilization. For many years it was customary in Mexico to build a factory located more or less centrally within a concentration of native guayule. The practice was to establish baling camps on the range where guayule could be baled and shipped, usually by burro back, to the factory for processing. Scant regard was paid to any sustained yield method of harvesting, and, inasmuch as the peons were paid on a per weight basis, many areas were completely denuded of all shrubs worth the pulling. It was assumed that areas so handled would have guayule growth completely reestablished in a short while and that they would be ready for reharvest. This did not always follow, and, as a result of this policy so similar to the " cut out and get out " policy followed in many lumber camps in the United States, many mills had to close down for lack of raw material.

This heedless method of harvest was aggravated when the price of crude guayule went to a dollar and a quarter a pound. Regulations were established which prohibited the pulling of plants whose diameter at the ground line was less than that of a man's thumb. The " rule of thumb " apparently was not followed very conscientiously. At any rate, factory after factory closed down until the four operated by the Mexican Continental Rubber Company were about the only ones remaining and their shrub supplies were getting short.

The Mexican Continental people had foreseen an eventual failure in their wild shrub resources and in 1910 hired the late W. B. McCallum to carry out cultural experiments at Torreon. He had some minor successes there, but in 1912 the Mexican revolution broke out and threatened the program. The decision was made to move all cultural operations out of Mexico into the United States, but such a plan was apparently to be stymied by a refusal to permit guayule seeds to leave the country. Dr. McCallum related to the author the manner in which he circumvented this difficulty.

The worthy Doctor was a thrifty Scot who, for the sake of economy, habitually smoked a short-stemmed, blackened briar pipe. His tobacco was a very common variety packed in a pocket-sized tin. When he approached the border and Pancho Villa's guards, whom he knew had been instructed to search him, he removed the paper envelope containing his pipe tobacco from its tin and filled the tin nearly to the top with guayule seeds. The envelope with its tobacco was then pressed back into the tin to hide the seeds. The border search took place as expected, but the guayule seeds remained undiscovered, and not a crumb of tobacco was wasted.

Early Culture in the United States. Preliminary surveys had indicated that many of the California dry farmed lands would be suitable for guayule culture, particularly those in the small coastal valleys of the southern part of the State. Four hundred acres of land were purchased near Valley Center, north and east of San Diego, and in 1913–14 plantings of shrub were made from nursery-grown seedlings from Dr. McCallum's tobacco tin seed supply. Later, additional accessions of seeds were obtained from Mexico without difficulty.

This venture did not prove so successful as was hoped. Survival of the plantings was good and did provide a quantity of plants from which varietal selections were made. Growth was slow and, further, not enough acreage nearby was available to support full-scale factory operations.

Test plots had been spotted throughout California and the Southwest. Among the more promising of these was one in south central Arizona. At that time this was virgin land and was susceptible to irrigation. In 1916 a large tract of this land south of Tucson was purchased by the Company. McCallum moved his headquarters to Arizona and established the settlement "Continental", named after the parent company. Again success in plantation culture of guayule was meager. He attributed the failure to the wide temperature variations between the hot summers and the cold winter nights. He was also unable to regulate the irrigation so as to obtain the best results, and while he succeeded in growing large plants, they contained little rubber[3].

He had found in his experiences in Valley Center that wild guayule exists in an almost infinite number of strains. Some of these made lots of rubber and others almost none. The work of variety selection continued. It was painstakingly slow and aggravating work. The appearance and actual botanical differences between good and bad strains were minute, and there was always the chance that the good and poor varieties might get mixed up. Occasionally he would isolate a very large specimen whose rubber content was high, only to find that it was completely sterile and never produced a seed. Eventually, however, he did establish several true breeding stains that were decidedly better than material from the mill run of wild seed. During this period indicator plot work was expanded, and on the basis of results from these test plantings it was decided that the Salinas Valley in California offered the best combination of climate, soil and available land.

Headquarters were moved to Salinas in 1925. Within the next few years about 8,000 acres of guayule were planted largely in the Salinas Valley. All acreages except the nurseries were dry farmed. An extraction mill or factory was also built a few miles south of Salinas, patterned primarily after the one at Torreon, and included the newest innovations in processing which promised to lower the costs of production. In the meantime the rapid spread of irrigation

[3] Later experimentation has shown that, by proper manipulation of irrigation, large plants with a high rubber content can be produced.

in the Salinas Valley coupled with the slump in rubber prices in the mid thirties resulted in many of the contracting farmers plowing up or burning their fields. Between 1931 and 1941 four factory campaigns were run through the Salinas mill which produced 3,068,630 pounds of crude rubber for an average of about 700 pounds of rubber per acre.

FIG. 1. A young guayule field in the Salinas Valley of California.

Guayule as a Military Asset

Prewar Interest. Early in 1930 the War Department sent Major Gilbert Van B. Wilkes and Major Dwight D. Eisenhower into the Salinas Valley to study guayule. These two officers made a thorough investigation of both field and factory operations and in their report, dated June 6, 1930, commented very favorably on the possibilities of guayule as an economic farm crop in the United States. Their report placed considerable emphasis on the advisability of establishing guayule as a farm crop to build up a domestic supply of natural rubber upon which reliance could be placed in the event of a "grave emergency", and to afford some protection to American consumers from possible commercial combines in the Far East. They further pointed out that many farmers in the dryland areas of southwest United States earn a precarious living from crops originally developed in the humid areas of Europe and Asia. The threat of crop failure is constant, and when conditions are just right for successful production, their produce must be sold in markets already abundantly supplied from closer sources. In summation they stated, "We are personally convinced that under real encouragement the production of guayule rubber would develop rapidly into an important industry in the United States".

Guayule in World War II. There was no further governmental interest in guayule for some time until the outbreak of World War II and the cutting of our supply lines to the rubber of the Far East. On March 5, 1942, the 77th Congress passed and the President signed Senate Bill 2282 as Public Law 473. Negotiations for the purchase of all the holdings of the Intercontinental Rubber Company in the United States by the Government were started before S-2282 was passed. These activities were financed by an allocation of emergency funds by the President. An agreement as to price was reached with Intercontinental on February 26, and work by "The Emergency Rubber Project" began at once.

The principal properties transferred to the Government by Intercontinental included 1,483 acres of land, on 674 of which there were growing shrub, Spence mill at Salinas, 22,867 pounds of guayule seed and 14 million seedlings growing in one small nursery. In addition, there were acquired some buildings, equipment, tools and supplies. Of great assistance to the infant Emergency Rubber Project were some of the personnel of the Intercontinental Rubber Company, including the late W. B. McCallum, Manager, who might be considered the father of the guayule industry in California; C. A. Lee, Superintendent; and Ralph Hastings, Mill Superintendent. The know-how of these three men constituted the base on which the Emergency Rubber Project conducted its operations.

The planting of 75,000 acres of guayule was authorized. The meager resources of seed and plantations made the task a monumental one. The Department of Agriculture was assigned the task of carrying out the work of the Project. Six months after the original goal was established it was increased to 500,000 acres. Efforts to meet the expansion got under way. It has been said that no nearer complete or better coordinated organization plan had ever been prepared in Government. No one will ever know whether it was as good as it looked because when the organization was ready to begin work, the expansion was halted to minimize interference with food production. The Project was ordered to maintain a "stand-by" position. Then on August 17, 1943, the Rubber Director suggested to the Secretary of Agriculture an expansion up to 20,000 tons of rubber per year, but after five months of waiting with all personnel assembled for key staff positions, Congress voted disapproval. The Project finally settled down as a farming enterprise on some 30,000 acres in California and remained on that basis until final liquidation was ordered.

On November 30, 1945, the Project was ordered liquidated and on December 14 Spence Mill produced its last pound of rubber. In its brief and hectic career during three and a half years, 60,000 acres of land were leased and 31,689 of these were planted to shrub. Most of the land was leased in California, a few hundred acres in Arizona and Texas. 2,900 acres were put under overhead sprinkling systems and produced 1,037,000,000 seedlings. Harvests were made from 6,048 acres of plantation shrub, from 2,540 acres of wild shrub in Texas and from the remnant of 30-year-old plants left by Intercontinental planting at Valley Center, California. A total of 2,947,273 pounds of rubber were produced and shipped to the Office of Rubber Reserve of the Reconstruction Finance Corporation. A portion of this rubber was used as the sealing agent in bullet-proof fuel cells for military aircraft and torpedo boats where it was highly successful. One new mill at Bakersfield, California, had been constructed and put in operation.

Liquidation of the Project resulted in the destruction of 21,000,000 pounds of

rubber standing in the fields in December, 1946. Production and sale of this 21,000,000 pounds of rubber would have greatly reduced the calculated per pound cost of the small amount of rubber actually produced in war time. Other factors contributed to the computed high cost. The Project was a wartime emergency business. It operated under orders to get the rubber regardless of cost. High overhead costs were engendered by frequent fluctuations in the scope of Project goals, with purchasing and personnel constantly geared to meet expansions that never materalized.

Post-War Guayule

The Emergency Rubber Project at an end, it appeared that guayule had sung its swan song, for at that time no provision was made for even a token program in research. Mexico had virtually destroyed its supplies of native shrub to meet American demands for rubber, and the American plantations had either been plowed under or burned. Somewhat later, however, it was felt that a research program should be initiated because rubber still remained a critical material. Finally the Office of Naval Research entered into a contract with Stanford Research Institute to carry on a limited amount of investigations. Essentially this was a stop-gap until Federal measures could get under way. On July 23, 1946, the current research program of the Department of Agriculture was authorized by Public Law 520 of the 79th Congress, which directed the Secretary of Agriculture to conduct research on agricultural materials declared strategic and critical by the Munitions Board. The program was initiated on August 1, 1947, and continues at this writing.

Objectives of Current Research. Work now being conducted jointly by the Bureau of Plant Industry, Soils, and Agricultural Engineering and the Bureau of Agricultural and Industrial Chemistry calls for: (*a*) investigation of the most favorable areas for producing rubber in an emergency with the special aim to determine the economic possibilities for production in a vast area of potentially suitable drylands in Texas; (*b*) maintenance of an adequate supply of seed for emergency planting and for the rapid multiplication of new strains or varieties as they are developed; (*c*) intensive investigation of increasing the productive capacity of the plant and its adaptation to economically favorable productive areas; (*d*) development through laboratory and pilot plant investigations of improved and new processes and equipment for the economical production of a high yield of a high grade, stable crude rubber; and (*e*) investigation of possible uses for by-products from rubber extractions and purification.

Because of budgetry limitations, current research is not being carried out with the same degree of intensity in all lines. The following discussion will deal mostly with those phases of work on which major emphasis is being placed, namely, plant breeding, process research and development, and characterization of the resinous components of the plant.

Plant Breeding. Very little plant breeding work has actually been done on guayule, and Dr. McCallum was of the opinion that hybridization is not feasible. All of his work was performed on the basis of strain selection with the major part of his attention being focussed upon the establishment of varieties with the highest rubber content that would reproduce themselves consistently and be adaptable to field culture. It was already known that most of the rubber in guayule is in the " bark ", and this led McCallum to the segregation of strains which had the greatest volume of cortical tissues. His varieties are perhaps best typified by Variety 593 which throws out a great number of relatively small branches just above the ground line and

rarely exceeds two and a half feet in height. The result is a dense and symmetrical shrub which is merely an accentuation of the normal growth habit.

Lloyd (3) had observed a similarity between guayule and mariola (*Parthenium incanum* H.B.K.) in certain wild plants, but apparently the possibility of interspecific hybridization did not occur to him. Rollins (5) has cited McCallum to the effect that certain of his plants were crosses between guayule and mariola. In spite of such evidence, American scientists did not investigate the plant breeding aspects of guayule, although as long ago as 1932 the Russians had undertaken cytological work on guayule (1).

When wartime exigencies demanded as much guayule rubber as could be obtained, a corps of American plant breeders were assembled as quickly as possible. Plant breeding, to produce really effective results, is a long-time endeavor, and the war was over before practical advances from the work on guayule were obtained. The basic ground work, however, was successfully laid for subsequent investigators to follow. It was established that guayule can be crossed with other species of the genus, but such crosses were not so readily obtained as with most farm crops. The basic cause of the difficulty experienced in obtaining hybridization of guayule with other species is the fact that guayule predominantly reproduces apomictically, that is, it produces viable seeds without sexual fertilization. Tysdal (7) has said that this may be true in as many as 90 percent of the cases, depending, of course, upon the chromosome number of the parent plant. Somatic chromosome numbers in guayule vary from 36 to over 100, and both sexual (diploid) and apomict (polyploid) forms appear. When crossbreeding guayule with other species is carried out, both sexual and apomict hybrids are produced by proper manipulation (7). This fact puts guayule in a unique place so far as plant breeding is concerned. The writer knows of no other agricultural crop that is so amenable to the desires of the plant breeder because important characteristics can be combined by hybridization and backcrossing; then the hybrid can be fixed so that it will reproduce for generation after generation without change.

Some of the possibilities in hybridizing guayule with other species of the same genus include crosses with *P. incanum*, *P. tomentosum*, *P. fruticosum*, *P. stramonium* and *P. Lozanium*. Herbaceous species include *P. hispidum*, *P. lyratum*, *P. hysterophorous* and *P. bipinnatifidum*. Not all have been studied thoroughly, but guayule alone contains appreciable amounts of rubber. Of first importance, of course, was the question, "If guayule can be crossbred with other species, will the progeny carry any rubber?" Analysis of branch samples from some of the earliest hybrids established the fact that some of the hybrids at least did carry rubber and in considerable amount. From then on the plant breeder's field offered great possibilities.

Among the more promising species is the near giant of the clan, *P. stramonium*. Some idea of the comparative size of the two species is shown in Fig. 2. This species, which reproduces sexually, crosses readily with guayule to form hybrids that show great vigor. *P. stramonium* has 36 somatic chromosomes; hence if guayule parents are selected which have 54 or 72 chromosomes, apomictic hybrids are produced which are fixed and breed true. On the other hand, if the guayule parent selected has only 36 chromosomes, sexual forms are produced which in the second generation show segregation of the various characteristic types. Continued crossing or selection of the segregated types may be made at will, and when a desirable form results it may be fixed and continue to breed true. Because of these characteristics guayule

FIG. 2. Comparative sizes of different species of *Parthenium* at the same age. Guayule (*P. argentatum*) on the left and *P. stramonium* on the right. (*Courtesy Bureau of Plant Industry, Soils and Agricultural Engineering.*)

might be classed as a plant breeder's dream come true.

It is far too early for all possible results to have been obtained from guayule breeding. The most intensive work so far has been carried out with *P. stramonium*, and one fixed strain has been developed which, according to chemical analysis, will produce at the same age 40 to 50 percent more rubber per acre than the best prewar strains of guayule. This is due to a greater tonnage of shrub per acre rather than to an increased concentration of rubber in the shrub. There remains to be established the adaptability of this plant to environmental conditions other than those found in the Salinas Valley.

Although the establishment of this one strain is a remarkable step forward, it is only the first step. An intensive program of back-crossing and hybridization of the new strains, perhaps with other species, holds almost unlimited possibilities for building up rubber productivity, disease resistance and cold tolerance. The plant breeders are confident that they can raise rubber production per acre 80 to 90 percent over what it was in 1942. It might be noted in passing that guayule, and its related species for the most part, are subject to few diseases and insect pests when growing under feral conditions. It is reasonable to assume, however, that, as with other agricultural crops, disease and insects will become somewhat more troublesome as agricultural production increases.

Limited field test plantings are being made of guayule and its hybrids in other parts of California and in Texas, and the usual agronomic and adaptability studies are being carried out as rapidly as possible.

Process Research and Development. In guayule the rubber hydrocarbon is suspended in latex as in other rubber-bearing plants. However, the latex in guayule is not borne in long tubes or ducts but makes up the contents of single cells. The parenchyma cells in which the latex is found are relatively thin-walled, have roughly equal dimensions along each of their three axes, and are found principally in the cortical tissues, in the medullary rays and in the pith. Because they are not interconnected, the latex cannot flow readily from one cell to the next. This form of structure has precluded the removal of rubber from guayule by tapping, as is done with *Hevea*, and heretofore has necessitated harvesting of the complete plant. Recent work in harvesting methods has indicated that pollarding or rattooning is a feasible method of harvest. This consists of mowing the tops of the plants, leaving the crown and root system intact, much as is done with alfalfa. This would permit successive crops of rubber from the same plant and would eliminate the cost of reestablishing plantations after harvest. Rattooning has to be done at the right time of the year to obtain good regrowth.

The earliest work in removal of rubber from guayule was essentially a chemical process developed by German investigators. It consisted of extracting the rubber from macerated plant material by organic solvents, such as benzene or toluene. It was scant wonder the German scientists were not enthusiastic about the product, for rubber removed from guayule in this manner is a black gooey mess resembling a poor grade of road tar. An acceptable grade of rubber has been produced by solvent extraction methods in the laboratory, but it does not appear promising for factory-scale operations.

The mechanical method, devised by William A. Lawrence, soon replaced the chemical method. Lawrence's process basically is the process that is in use today. It consisted, in Lawrence's time, of cutting up the dried shrub with some type of mechanical cutter or corrugated rollers sprinkled with water. The shrub might or might not be washed prior to its

original comminution. After being comminuted, the ground shrub was placed in a cylindrical steel mill lined with Belgian flint bricks and charged with Norwegian flint pebbles. Water was added to form a slurry, the pebble mill was closed and milling was carried out for about two hours. The slurry was then discharged into a flotation tank where the major portion of the plant fibers settled out and the cork and rubber floated on the surface. In the earlier development of the mechanical process the cork was removed from the rubber by allowing the mixture to stand in water-filled vats until the plant material, other than rubber, decayed, became water-logged and sank. The stench of this operation was extreme and the process was time-consuming. These two items encouraged the development of pressure treatment vessels called " pailas " to waterlog the cork.

The so-called " purified " rubber after decorking was sheeted out on rolls to remove a large part of the water, after which the product was considered ready for the market. In this state it was composed of rubber hydrocarbon, considerable plant debris, some resins and about 25 percent water.

As time went along the process was modified here and there. Addition of water to the crushing rolls was abandoned, and batch pebble mills were replaced by continuous tube mills. The use of pebbles as milling agents was continued, however. Pressure for decorking in the pailas was stepped up to obtain a cleaner product. In 1942 hydraulic pressures of about 500 pounds per square inch were in vogue, and the retention time under pressure was two hours. This was a constant stumbling block because it constituted a batch operation in what otherwise was a continuous process, and it required more manpower than should have been needed. During the second World War engineers of the Bureau of Agricultural and Industrial Chemistry developed an automatic high pressure decorking device which they euphoniously called a " baica ". This machine used pressures of 2000 p.s.i. and reduced decorking time from hours to seconds, as well as eliminated virtually all human attention to the process.

Drying the rubber " worms ", as the coagula from the pebble mills are called, proved to be a headache for a long time. In the very earliest process the rubber was sold wet. Continued objections from the managers of consuming factories necessitated some form of drying. Original drying was done by hanging the rubber sheets in a darkened room to dry. Further efforts in improvement of the crudes brought about the use of vacuum ovens for drying. The rubber worms were loaded and spread by hand on large sheet iron trays. These overgrown cookie tins were then charged into vacuum ovens where they were left usually for four hours. The operator would then open the oven and examine the rubber by texture, appearance and odor to see whether it was dry. If it was not, the trays would be replaced to be baked another hour or so. When done, the rubber was scraped from the trays by hand, pressed into 100-pound blocks and boxed for shipment.

The third and definitely improved step in drying, as developed by engineers of Agricultural and Industrial Chemistry, added another feather to their hats. They found by close examination of the rubber worms that they were like little sausages, about the size of a grain of rice or wheat filled with tiny canals and crevices, and that exposure of the worms to sudden high heat caused them to glaze over on the outside, thus trapping the water inside from where it could not be removed except by long exposure at high temperature. They discovered also that if the worms were warmed gently at first, then in progressively higher temperatures, they could be dried in a much

shorter time and that drying could be done at atmospheric pressure without undue deterioration. This knowledge permitted the design of continuous belt, through circulation dryers in which the rubber was dried thoroughly in something less than an hour. It eliminated also a large amount of hand labor and made the process markedly cheaper.

Guayule crude rubber contains little or no natural antioxidant or preservative, as does tree rubber, and the dried rubber sheets were, more often than not, sticky and unmanageable. It is not known just when the first antioxidant was applied nor what it was. For quite a while the rubber sheets were dipped in what was called " wood tar " before drying, and while this helped it did not completely overcome the problem. In later years many different materials were used for their antioxidant properties, and, while some of them were good antioxidants, they all had objectionable features which made them more or less unsatisfactory from the manufacturer's point of view. The problem of a suitable antioxidant is still an open field for the investigator and is one of the more important lines of research being carried on today.

That, then, is about where process research stood when the current program got under way. A method of getting the rubber out of the shrub had evolved through the course of years that was more or less successful. True enough, much of the machinery seemed more suitable for the recovery of minerals from their base ores, but, since many of the steps in the process were developed by men with mining engineering experience, this is not strange.

As mentioned earlier, all commercial processing has used dried shrub. Just how this started is not clear, but probably it was a natural outgrowth from the facts that the shrub was gathered on the range far from the mills and that by the time it reached its destination by man back, burro back, carts and trains, it was thoroughly dry. At any rate, for years it was thought necessary to reduce the moisture to 12–13 percent to bring about coagulation of the rubber. The whole problem hinged on the kind of treatment the shrub should receive between the time of harvest and milling. All these problems were lumped together under the term " conditioning "[4].

The problem of conditioning extends back to the very early days of guayule. Some of the earliest workers in the field insisted the shrub should be defoliated before being baled in order to obtain the best rubber. This operation was not so simple as it seemed at first glance, since guayule leaves have no abscission layer and leaf cast is not a normal part of the plant's life process. Chemical defoliants were unknown in those days, but they would have been of scant value anyhow, since these chemicals work primarily by speeding up maturation of the abscission layer. Immersing the plants in boiling water for ten minutes or so, however, is effective, and the leaves will fall off the plants when shaken afterward. This practice was followed for years in Mexico but was finally abandoned. Intercontinental in the United States had not used defoliation at all in its factory operations, since preliminary comminution of the shrub was carried out in the field where " parboiling " and defoliation were impractical.

The Emergency Rubber Project took up defoliation again, but for reasons quite apart from any effect it might have on conditioning. The Project was to

[4] The term " condition ", as applied to shrub to be milled, is used to denote the physiochemical state of the shrub and its constituents. The " optimum condition " is that at which the maximum amount of crude rubber of acceptable physical quality can be removed by conventional pebble milling processes. " Conditioning " refers to the methods used to obtain the closest possible approach to the optimum condition.

harvest shrub two years of age. Leaves make up about 20 percent of the dry weight of shrub of this age class, and, since the leaves contain no rubber that can be obtained by milling, it was desirable to reduce the non-productive load on the mill circuit. Later it was found that leaves contain rather large amounts of contaminants which are deleterious to the keeping quality of crude rubber, so leaf removal is desirable for that reason.

But to return to conditioning. Intercontinental, still feeling that shrub moisture must be reduced to less than 20 percent for successful milling, had utilized "sunning" in the field after the shrub was dug, since sunshine is a cheap form of heat. Furthermore, extensive moisture loss in the field reduced the tonnage that had to be hauled to mill. The Emergency Rubber Project followed the same pattern of operations and supplemented "field curing" (which the writer prefers to the term "sunning") by application of artificial heat between the cutting and crushing operations. The Project also followed the practice, earlier developed in Mexico, of storing shrub to be milled in large warehouses, or bodegas, and of defoliating the plants just before they started into the milling circuit. The varied periods of field curing, the equally varied geographical conditions under which it was done and the unequal periods of storage in the bodegas all combined to result in a raw material to the mills whose lack of uniformity was extreme. This made uniform maximum recovery difficult to obtain in a fixed continuous milling system and naturally resulted in an end product that was quite as non-uniform as the raw material. Continual efforts to correct this situation brought about a revived interest in retting.

Retting, which is a partial disintegration of the plant tissues by mixtures of aerobic bacteria and fungi, had been advanced by Spence (6). It was his claim that retting increases the uniformity of the crude rubber and, in addition, decreases the resin content. A low resin content is desirable because resins detract from the physical properties of the rubber. Spence had not been able to carry out retting successfully on a factory scale, and most of the attempts by the Emergency Rubber Project were equally as futile. Eventually it was found that fairly successful large scale rets could be carried out if the shrub was dug, baled and brought in from the field without delay. The bales were then parboiled, defoliated, rebaled and stored in the bodega for 30 days. This seemed a good solution to the conditioning problem, at least in the Salinas Valley, but it was doubtful that it would be so successful under other climatic conditions. In addition, "bale retting", as it was termed, involved the action of a mixed microfloral population, and quite conceivably undesirable as well as desirable microflora might be present. To overcome these probable difficulties, an investigation was started to determine whether pure culture, controlled rets could be carried out. Small scale rets of this nature were successful in the laboratory but were never carried out en masse.

In the present research work, considerable thought has been given to retting with the conclusion that the capital investment and subsequent operating costs necessary for pure culture retting cannot be economically justified when the end product sells for as low a price as does crude rubber. This conclusion reopened the entire field of shrub conditioning. A different attack was made on the problem which involved a basic study of the rubber in the shrub and what happened to it during conditioning. During the course of the investigation it was revealed that any appreciable delay between harvest and milling is deleterious to the rubber, regardless of whether that delay occurs during field curing or in

bale retting. In either instance the delay was accompanied by a drop in the molecular weight of the rubber and a corresponding decrease in Mooney viscosity values. The drop in Mooney values is only partly compensated for by the decrease of resins in bale retting. Any apparent increase in rubber quality is attributed to the loss in resin rather than to an actual improvement in the rubber hydrocarbon.

These findings led directly to a consideration of deresination to improve rubber quality. It is known, of course, that the resins are soluble in various organic solvents such as acetone, ethanol and furfural. Use has been made of this knowledge in making chemical analyses of plant material and crude rubber, and from time to time attempts have been made to produce a deresinated guayule crude rubber on a commercial scale. On the whole, these attempts have been less than successful, but in part at least the lack of success may be attributable to the fact that some degradation of the rubber had already occurred in the shrub conditioning. With this knowledge, research work has been directed to the classification and characterization of the various components of the resin and to the development of means for eliminating the resins from the rubber.

There are two modes of attack on this latter problem. In one the rubber and resins may be recovered from the shrub, after which the crude rubber may be deresinated. In the alternative method the shrub may be deresinated prior to removal of the rubber by milling. Small batches of very high quality rubber have been produced by both methods, but a great deal remains to be done to determine which method should ultimately be adopted for commercial use. Obviously if the resins have market value it would pay to deresinate the shrub instead of the crude rubber, since larger amounts of resin can be obtained. If the resin has no value, it might pay to deresinate the crude, since a smaller volume of material would have to be handled. Whichever method is selected will require much study in order to develop the continuous extractors and other equipment which will be needed to accomplish the deresination and permit recovery of the solvent. A diagrammatic flow chart of a conventional and alternative mill system is shown in Fig. 3.

In the meantime handling the shrub from field to mill still presents a problem. At this writing it appears that for either resinous or deresinated crudes the shrub should be brought in from the field with a minimum delay after harvest, and it should be milled as soon as it reaches the factory. In case resinous rubber is to be produced, special techniques for handling the " lush " or fresh shrub are required to prevent excessive losses of rubber as latex dispersions in the mill liquor. Some ways of bringing about coagulation by mechanical means are known, but the best method remains to be developed. This is not a problem when shrub is deresinated because the resin solvent coagulates the latex. If some means for holding the shrub between harvest and milling can not be worked out, it might mean that factory operations would have to be suspended for some portion of the year, since it is economically wise to harvest the shrub at the time when rubber increment is at the maximum.

Incidentally the reader may inquire, " If milling fresh shrub results in some latex dispersion, why not recover all the rubber as latex? " Work has been done along these lines, and guayule latex does result in an excellent grade of rubber. Recovery of rubber as latex presents several problems in that it is difficult to disperse the latex, particularly when leaves are present, and parboiling to remove the leaves coagulates part of the rubber. Such dispersions as have been prepared

are so dilute that concentration to a usable product is difficult. The total amount of rubber that can be recovered in this manner is lower than can be recovered in solid form, and continuous commercial-scale machine development for latex recovery does not appear practical at this time.

There are other phases of processing and that considerable by-passing or short-circuiting can and does occur in an open system like the tube mill. Furthermore, the grinding action of the pebbles brings about incorporation of undesirable amounts of plant debris in the crude rubber. Some preliminary work indicates a good possibility for the utilization of a papermaking jordan in place of the tube

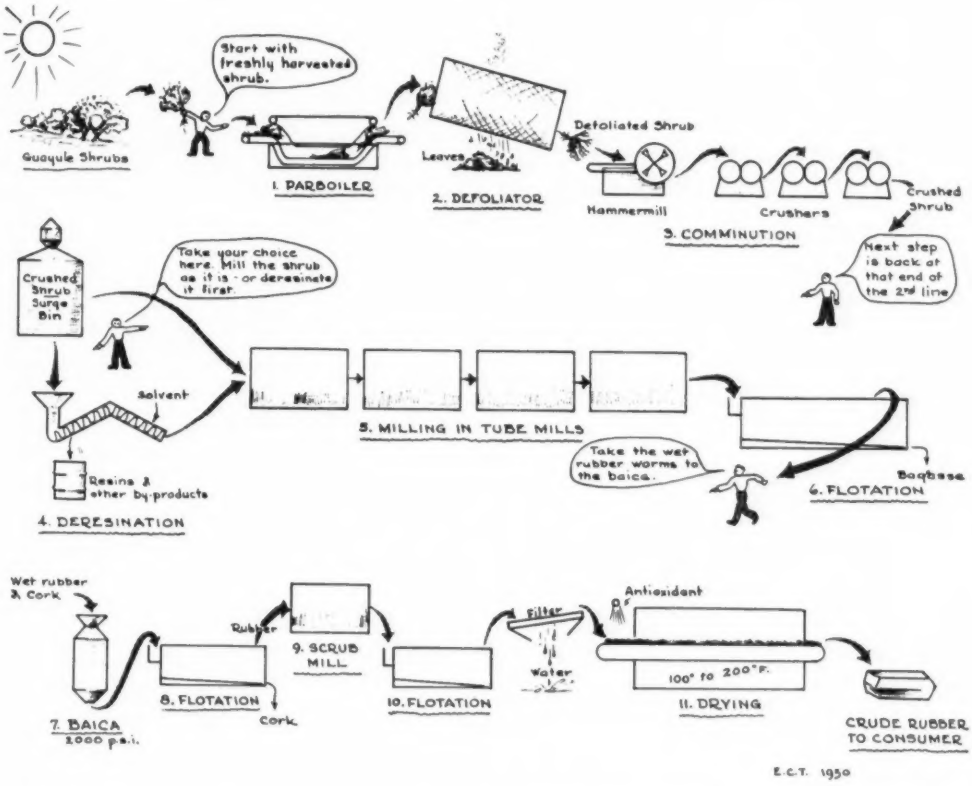

FIG. 3. Flow chart illustrating various steps and alternatives in processing guayule for rubber.

guayule for rubber that require research. A few of these will be discussed briefly. The tube pebble mill has been accepted as the best continuous milling mechanism developed to date. Its use requires large amounts of heavy pebbles for milling, and it seems a cumbersome contrivance to bring about agglomeration of rubber, especially when it is considered that guayule is a rather light weight material

mills. Rubbers of good quality have been obtained by the use of a jordan, but much remains to be done in the field of machine development before the jordan can be adopted by industry for milling guayule.

Most of the flotation systems for separating the cork and rubber from the rest of the plant material have been adaptations of ore refining machinery. These

primarily involve sedimentation rather than flotation, and it seems that a better system could be devised. As a matter of fact, rectangular tank flotation systems have been constructed that are better than some of the older equipment. The rather recently developed centrifugal filtration machinery which can be operated continuously seems to hold considerable promise for separation of the bagasse from the rubber and flotation liquor. Here again it is probable that machine development and modification will be the principal field of work.

Prevention of oxidation in guayule rubber is essential to the production of a stable material which can be stored until needed. Probably the removal or inactivation of resins will not be the only answer to the production of a stable crude rubber. Guayule, unlike Hevea, does not contain natural antioxidant substances, and suitable antioxidants must be developed and tested to achieve maximum stability.

Finally there is the opportunity for increased mechanization and instrument control in most if not all steps in the process. Continued research over a period of years will undoubtedly result in simplification of mill design and operation, and thus materially reduce processing costs.

By-Product Possibilities. Concomitant with process research and development there is the possibility of by-product utilization. This is particularly true with respect to deresination because the various components of the resin appear to have economic possibilities. Research on guayule has uncovered many interesting compounds, some of which may prove valuable by-products. They include essential oils which might be useful as substitutes for turpentine or for cosmetics and perfumery; parthenyl cinnamate from which cinnamic acid could be derived for use in perfumery and various pharmaceuticals; resin "X", unidentified as yet, but a polymerizable fraction that seems promising for use in paints and varnishes; a high melting point white wax that might well be used in place of carnauba; and a number of other chemicals which may be useful as reagents in organic synthesis.

By-product investigations as such have largely been discontinued, but the work on resin characterization continues, since resin or some of its fractions appear to be catalysts of oxidation. There are other by-products, some of which are pretty well proven, and others whose possibilities have not been explored. Bagasse, for instance, has been utilized as a source of fuel in the guayule mills both in Mexico and in the United States. In Mexico bagasse drying has been accomplished by solar evaporation and requires considerable labor. In the United States such drying has been done by utilizing the otherwise wasted heat from the stack gases. Future guayule mills will probably get most if not all their heat requirements by using bagasse as fuel. The leaves have been shown to be useful as fertilizer and, if properly composted, are as good as any leaf mold that can be obtained. During the second World War quantities of leaves were utilized by farmers in the Salinas Valley as top dressing for some of the most valuable vegetable lands in the Nation. The cork, too, may prove to be of considerable value. The mill liquor from a guayule factory contains rather large amounts of water-soluble materials such as levulin, inulin and pentosans. In the past, the mill liquor has been discarded as waste, but it seems possible that the water-solubles might be built up by recirculation of the mill water until the concentration is high enough for production of industrial alcohol by fermentation methods. Although scarcely a by-product possibility, it is worth noting, perhaps,

that guayule seed has a protein content of 11 to 14 percent and that the seeds have been used in mixed stock feeds.

Guayule's Future

Any discussion of the long-time future of guayule must be based on world economics and international trade relations. Let us take a brief look at guayule elsewhere in the world. That may be a clue as to what we should do.

Mexico, guayule's native home, does not apparently present much of an immediate future for guayule. The wild stands have been decimated, and the areas suitable for its growth are not suitable for extensive cultivation because of the shortage and poor quality of irrigation water. It is probable that the guayule industry in Mexico will depend upon regeneration of the wild stands which will take years.

Australia is dependent upon the freedom of the sea lanes for her supply of natural rubber, and her future synthetic rubber production is a dim view indeed because they have no oil for butadiene synthesis. Australia is anxious to become independent of foreign sources of rubber and started guayule investigations at the beginning of the last decade. These investigations are still being pursued.

Turkey has decided to raise her own rubber and to that end has turned to guayule. Her needs are small, to be sure, but it is undestood that guayule has nearly if not quite supplanted all other rubbers in Turkey.

Argentina has inaugurated an extensive program, and, while recent information is lacking, several thousands of acres were ready for the first harvest in 1947.

Over 20 years ago Spain and Italy both put in a number of test plantings of guayule. Spain, of course, confined her efforts to the mainland, but Italy was of the opinion that the rubber-producing shrub would have great value in her African colonies as well as at home. Nothing seems to be known about the Italian venture and for a long time Spain seemed to lose interest. Recent information, however, has it that Spanish guayule is being grown and that some rubber production is expected this year.

For a good many years the Russians have been working toward establishment of their own supplies of natural rubber. The Soviets have done a lot of work on the so-called Russian dandelions, and they are known to have a good many thousand acres of these plants now under cultivation. They also worked with guayule and years ago started breeding and selection work. Precise information is understandably difficult to obtain, but in 1945 the writer was informed that guayule in terms of "thousands of hectares" was being grown somewhere between Tiflis and Baku. While current information about Russian guayule is lacking, it is safe to assume that the Russians aren't overlooking any good bets.

Guayule as a Farm Crop in the United States. There are areas in Texas totalling over three million acres, somewhat larger than the State of Connecticut, where a supplementary agricultural crop is needed. At present peanuts, sorghums, sudan grass, watermelons and some cotton are the main farm crops and seldom return incomes to the farmers comparable to the other agricultural areas. Much of the region is now brush land and is largely non-productive, providing only mediocre grazing, even when cleared. Arizona has several hundred thousand acres of land with limited water rights but with adequate water to produce splendid guayule. The soil characteristics of all these areas are suitable for guayule. Plant breeding work which would increase the cold resistance in guayule by only 5° F. would increase the

potential area more than threefold. The land for producing guayule in the United States is unquestionably available.

Production under dry land culture is quite simple. Nurseries are required for growing the transplant stocks, but recent research points to much cheaper production of nursery stock than was possible with the older overhead watering system. When the seedlings are grown to transplant size they may be put in the field at once or they may be held in the nursery beds for two or three years and still provide transplantable stock. Land preparation for field plantations would consist of one plowing and two harrowings, and the transplanting itself its done with machine planters that involve a minimum of hand labor. The only cultural treatment required thereafter would be three machine cultivations per year and possibly only one hand hoeing for each of the first two years. Additional experimentation with selective herbicides or oil sprays might entirely eliminate the need for hand hoeing. Harvesting as now visualized would consist of mowing the plants at the end of three years in the field, then after two years regrowth the entire plant would be harvested by digging. It is probable that guayule farming will be most successful if carried out on a fairly large scale, and it would be a simple matter to work out a rotation system where, after the first three years, harvests would be made annually.

During the first three years it is estimated that Variety 593 would produce a total of 715 pounds of crude rubber per acre. Of this amount about 70 percent, or say 500 pounds of rubber per acre, would be removed in the first harvest and an additional 330 pounds per acre would be obtained from the digging at the end of the fifth year. This is an annual average of 166 pounds of rubber per acre over the five-year rotation cycle and, if expanded to the potential acreage suitable for guayule, would amount to about five hundred million pounds of crude rubber per year. Variety 593 is one of the old "McCallum" varieties, and there is no question that continued plant breeding research will increase the per acre production by a minimum of 40 percent. It is apparent from this that the United States could produce seven hundred million pounds of crude natural rubber per year, and this is about half the natural rubber consumed in the United States in 1949.

The fact that the farmer would have to wait three years for the first crop is neither particularly unusual nor undesirable. In fruit-growing areas the orchardist must wait from three to seven years before he can harvest his first crop. Farm forestry operations, which are becoming more and more common throughout the United States, utilize rotations of many years duration. Very commonly a cattleman will wait two or three years before he puts his steers in the market. Furthermore, the farmer who is raising guayule is fortunate in that if the price of rubber happens to be down for a year he can postpone his harvest and wait until the price is more favorable. In the meantime his guayule plantation will be laying down more rubber. This is not true of any of the cereals, fruits, nuts or vegetables where the crop must be harvested when ready. Moreover, it is not a soil-depleting crop. And guayule has one more very important advantage. In those drouth years which come with pernicious persistence throughout its range, when all other crops burn up, guayule will continue to build up more rubber and wait for good weather.

Utilization of Guayule Rubber. Throughout the years Mexico has produced over 120,000 long tons of guayule rubber that found its way into nearly every rubber manufacturing market in the world. Chemically the rubber hydrocarbon molecule from guayule is the same as *Hevea* rubber, and the crudes

have been used for everything from overshoes to adhesive tape. Guayule rubber has excellent tack and adhesive properties, and was proven to be useful in the manufacture of plied articles, such as footwear, belting, hose and other mechanical goods where adhesiveness to fabrics is essential. Although unknown now, guayule tires were common in the early part of the century. An important use for guayule during World War II was in the construction of the inner sealing layer of bullet-proof gasoline tanks on airplanes and landing craft. Patents have been granted for the use of guayule rubber, resin, fiber and all combined with blown asphalt or other waterproof binder in the production of construction material (2).

The general utility of resinous guayule rubber, which we have dealt with in this brief discussion, is limited because of its high content of resins, lack of uniformity and instability of the crude during prolonged storage. Work conducted under the current research program has resulted in a superior deresinated product that has promise of being closely equivalent to *Hevea* rubber in most physical properties. Evaluation of this rubber is now in progress to determine its suitability for critical uses, particularly in the carcass of heavy duty truck tires. Preliminary results obtained to date bring the conviction that the guayule of tomorrow will be more widely used than any past product from " that plant from the Chihuahuan desert ".

Conclusion

Why the concern over natural rubber? Won't the synthetics fill all rubber needs? The answer is simply, " No! " Chemists the world over have taken tremendous strides in the syntheses of many elastomers, but to this day they have not been able to formulate any compound which alone or in combination with other compounds will replace natural rubber for all uses. Rubber authorities say that a minimum of about 20 percent of our rubber consumption must be natural rubber. To avoid the term " grave emergency " and to speak plainly, in the event of war natural rubber would be more imperative than ever. Truck tires, tank treads, self-sealing gas tanks—all of these and many more articles will not withstand the hard usage to which they will be exposed if made from synthetic rubber. Our whole economy runs on rubber, over 90 percent of our natural rubber supply is 15,000 miles away from our shores. With the spread of unrest over much of the Far Eastern sources, it is apparent that our natural rubber supply could easily be cut off. Obviously every effort should be made to grow our own.

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The Date Palm—"*Tree of Life*" *in the Subtropical Deserts*

Dates, staple food in the valleys of the Tigris, Euphrates and Nile rivers since the dawn of history, have been established on nearly 6,000 acres in southern California and Arizona.

ROY W. NIXON [1]

Antiquity of Date Culture

The date palm (*Phoenix dactylifera* L.) was one of the first fruit trees to be domesticated. Insofar as present records go, credit for this accomplishment must be given to the Sumerians who were probably cultivating dates as early as 3000 B.C. About that time representations of the date palm, often with fruit, began to appear on pottery and cylinder seals, and within a few hundred years references in cuneiform recorded that date gardens had become very extensive, that a number of varieties were cultivated and that the crop afforded one of the staple foods of the people (6, 23).

In Egypt it does not appear that date culture had become very important before the New Empire, or about the middle of the second millenium B.C.; but the date palm was present, known and utilized at a much earlier period. Date palm logs were used to roof royal tombs as early as about 2700 B.C. The antiquity of the date palm in Egypt is further attested by the fact that the words for "sweet" and "date" are identical; this suggests that by the time writing was invented the date was already known (15*a*).

Date culture has never been important in the valley of the Indus, where introduction of the date palm has been attributed by some to the soldiers of Alexander the Great in the 4th century B.C. and by others to the Moslem invasions at the beginning of the 8th century A.D., but if the date seeds reported by Marshall (13) from excavations at Mohenjo-daro are *Phoenix dactylifera*, then the date palm may have been in northwest India (now Pakistan) as early as 2000 B.C.

Origin of the Date Palm

The great antiquity and extent of date culture around the Persian Gulf suggest that the date palm may have originated in that region. On the other hand, since the species has apparently existed from prehistoric times in the tropical and subtropical zone between the Indus and the Nile valleys, probably extending as far as Senegal, either it was originally native over much of this area or it was spread by prehistoric man (4). Favoring the greater antiquity of the species in the eastern end of this zone is the fact that the nearest relative of the date palm is *Phoenix sylvestris* Roxb., sometimes called the wild date, which is native to India and which is not easily distinguished botanically from *P. dactylifera*. It is the only other species of *Phoenix* whose pollen applied to *P. dactylifera* has produced seed and fruit indistinguishable from those by pollinations with *P. dactylifera*. Pollens of the two African species, *P. reclinata* Jacq. and *P.*

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canariensis Chabaud, when applied to *P. dactylifera* produce seeds differing in size, shape and color, and fruit usually ripening later than any from pollinations within the species.

The presence of uncultivated date palms throughout the zone where we find it at the dawn of history can be accounted for by the probability that over a period of several thousand years preceding cultivation of the date palm, prehistoric man utilized its fruit and thus greatly extended the area over which it originally occurred, aiding unconsciously in the evolution of better edible fruit. Dates are easily transported and seeds grow readily in moist soil in a favorable climate.

Botany

The date palm is one of the most important members of the family Palmaceae. The genus *Phoenix* is distinguished from other genera of pinnate-leaved palms by the upward and lengthwise folding of the pinnae and the peculiarly furrowed seeds. There are about 12 species, all native to tropical or subtropical parts of Africa or southern Asia. Several of these are fairly well known as ornamentals, the most highly valued being *Phoenix canariensis* Chabaud, the Canary Island palm, extensively used along driveways and in parks across the extreme southern portion of the United States. *P. sylvestris* Roxb. is cultivated in India as a source of sugar. *P. dactylifera* is distinguished from the two species just mentioned by the production of axillary offshoots, or suckers, which occur chiefly near the base of the stem, and from other species by its tall, columnar, relatively thick trunk which attains an ultimate height of 60 to 80 feet or more (2). The trunk has only a single terminal bud, and, like nearly all other monocotyledons, lacks a cambium cylinder.

The date palm has a fibrous root system. Numerous adventitious roots, from one-fourth to one-half inch in diameter, arise from the base of the stem and penetrate the soil to depths of 20 feet or more. From these main roots branch smaller feeder roots. The date root has a structure adapted for growing in very moist soils. Outside the central portion (stele) of the root, which contains the main conducting tissues, there is a large peripheral (extrastelar) region filled with numerous air passages. Such passages are possessed by plants like rice, which thrive in very wet soils, but they are not found in plants like wheat, which do not tolerate such conditions (17).

The leaves of a mature date palm are large, ten to 20 feet in length. Each leaf has 100 to 250 pinnae, ten to 40 inches long, and in the lower portion of the blade a number of suppressed pinnae or spines which grade downward in size to an inch or less in length at the base. The tissue of the leaves is thick and tough, resistant to the wind and sand characteristic of the desert. The leaf is further protected against excessive loss of moisture by the very small size of the stomata which are sunken below the level of the exposed surface of the thick protecting cuticle in small pits, as is common only in zerophytic plants. There is no marked structural difference between the face and the back of the pinnae. The terminal bud and the sap-conducting tissues of the endogenous trunk are well protected by the crown and overlapping leaf bases above and by the trunk fibre and adherent portions of old leaf bases below. Altogether the structure of the aboveground parts of the date palm is peculiarly adapted for drought and heat resistance.

The date palm is dioecious, male (staminate) and female (pistillate) flowers being produced on separate palms in the axils of leaves of the previous year's growth. The inflorescence, or flower cluster, is a branched spadix and

is enclosed prior to maturity in a protecting sheath, or spathe. The female flowers are small, rounded and waxy-white, with six rudimentary stamens and three carpels. Only the three curved sessile stigmas, and sometimes the distal portion of the carpels, protrude slightly from the closely adhering perianth composed of three united sepals and three overlapping petals. The staminate or male flowers are more showy with six stamens surrounded by three larger petals extending beyond the cupular calyx. A single large inflorescence may contain 6000 to 8000 flowers.

The fruit of the date is a one-seeded berry. Its development is characteristic. After pollination one of the carpels rapidly enlarges and suppresses the other two. An enlargement of one carpel may occur without pollination or there may be a slight growth of all three, but such parthenocarpic fruit develops very slowly, if at all. Inferior edible dates do occasionally develop without fertilization and hence without seeds. The color of the carpel, which is waxy-white in the freshly opened flower, becomes green after several days exposure, and this color is retained until the fruit has reached almost its maximum size. It then becomes, according to variety, either red or yellow or an intermediate combination with some red on a yellow background. A month or more after acquiring the red or yellow color the final ripening begins and the color changes to a shade varying from light straw or amber to a deep purple, almost black.

Products

The date palm supplies a large proportion of the necessities of life in the desert areas where it is grown. According to a poem of ancient Persia and Babylonia, quoted by both Strabo and Pliny, there were 360 uses of the date palm. The fruit has long been a staple and dependable food used in many combinations. An Arab proverb declares that a good housewife knows how to prepare dates a different way each day of the month (10). Syrup, a fermented liquor, alcohol and vinegar are derived from the fruit. When a palm is cut down the tender terminal bud is eaten as a vegetable or salad.

The fresh sap of the date palm, known as " lagmi ", makes a beverage comparable to the juice of sugar cane and is easily converted into a fermented liquor. As the method used for extraction of the sap involves drastic defoliation and exposure of tender tissue immediately above the bud, sometimes resulting in the death of the palm, only palms of little value for fruit production are used for this purpose.

Date logs supply crossbeams for ceilings, posts for other structures, and sweeps for wells. The leaves, sometimes used whole for thatched coverings, supply from the midribs, material for crates, furniture and fences; from the leaflets, baskets and thread; from the thorns, needles, pins and punches; from the petioles or leafbases, firewood; and from the fibre encircling the trunk, cordage, mattresses and occasionally low-grade clothing. Ropes are manufactured from the fruitstalks. Date seeds are ground and fed to camels and other stock; they are also occasionally used for necklaces and as a source of charcoal for silversmiths.

Production of blanched leaves for Palm Sunday celebrations is an important part of date culture at Elche, Spain, but only male palms are used for this purpose which involves complete defoliation every fourth year.

FIG. 1. A commercial date garden in Coachella Valley, Calif., consisting of Deglet Noor palms about 15 years old. Note the paper covers over the bunches, to protect the fruit from rain, and the high borders with irrigation water between. (*U.S.D.A. Circular 728*).

FIG. 2. Date gardens along the banks of the Shatt al Arab, the name given to the combined flow of the Tigris and Euphrates rivers from their junction to the Persian Gulf, a distance of over 100 miles. This is the largest date-growing district in the world.

In the partial shade of date palms other plants may be grown which would not survive without this tempering influence.

A Sacred Tree

The date palm contributed so much to the material needs of the early peoples who cultivated it that it soon came to be regarded as a sacred tree. It was not so much an object of worship as a symbol of fecundity and fertility (6). To the Sumerians the date palm was a tree of the knowledge of good and evil, which later became well-known through the story of the garden of Eden, tradition-

FIG. 3. Date gardens among the sand dunes of the Sahara in the Oued Souf of Algeria. (*Photo—OFALAC—Alger*)

FIG. 4 (*Upper*). Date gardens in the foothills of the Atlas Mountains at El Kantara, Algeria.

FIG. 5 (*Lower*). A date garden at Elche, Spain, showing method of planting dates in rows around plots in which other, low-growing crops are grown. This arrangement provides good aeration and exposure for palms and fruit in a climate where high humidity and low maximum temperatures are limiting factors in date culture.

ally located in Sumer. Veneration for the date palm became particularly marked among the Semitic people of the desert, who recognized their dependence upon it and eulogized it in their literature. No other plant contributed so much to make the desert habitable. To them it was in a very real sense a " tree of life ".

The importance of the date palm in Sumer and the unique and peculiar practices connected with its culture made

a deep impression upon the minds of neighboring peoples and caused it to be adopted as a sacred tree among subsequent civilizations, even where date culture itself was not important. Thus we find the date palm prominent in the bas reliefs of Assyria, north of the zone of date cultivation. The date palm was valued in ancient Greece for religious as well as ornamental purposes, and the Romans adopted it as an emblem of victory. Palm leaves were presented to the victors of games and became a mark of royalty, woven on the robes of emperors. To the Hebrews the date palm became a symbol of immortality, and when Rome became Christian this idea was adopted by the early church and palm leaves began to be used in religious celebrations.

Spread of Date Culture

The knowledge of date culture, developed under the stimulus of the civilizations of the valleys of the Tigris and Euphrates and the Nile, spread very early to the more important desert oases within their sphere of influence or communication. By means of seed carried in fruit, date palms were probably disseminated around the Mediterranean coast by early Phoenician traders. There are representations of date palms on Carthaginian money and on early burial plaques found in Spain.

Pliny mentions the occurrence of date palms around the Mediterranean coast and comments about date culture elsewhere; but there is no evidence that the Romans themselves did anything to extend that culture, although, since they made use of the fruit, it is quite likely that seeds carried in that way may have brought date palms into localities where there were none before. Elche, near the southeastern coast of Spain, is the only locality in Europe where an important commercial date culture has developed, although at Bordighera, Italy, there is a small group of date palms which supply Rome with palm leaves on Palm Sunday.

Introduction of date culture into the Saharan oases of what is now French North Africa is known to have begun near the end of the Roman Empire. It followed certain Berber immigrations and introduction of the camel in the 6th century A.D.; it appears to have been further stimulated by the Arab invasions beginning in the 7th century A.D. and by the subsequent pilgrimages of faithful Moslems back to their religious homeland in Arabia. In Mauritania the development of date culture was limited by scarcity of water. South of the great Sahara Desert of North Africa increasing rainfall imposed a barrier to any extension of date culture, which has been limited to small plantings along the northern edge of the equatorial rain belt from Senegal and the Upper Niger to the provinces of Darfur and Blue Nile in Sudan. There is apparently no record of date palms in Africa below the equator until very recently, and as yet there are only a few in certain districts in the Kalahara Desert.

Also of comparatively recent introduction are the few date palms in the desert region of Australia (South Australia, New South Wales and Queensland). During the last few decades the Russians have planted date seeds in some of the desert valleys of south central Asia north of Iran and Afghanistan, but in most of this area low temperature is a limiting factor.

Seeds from dates carried as provisions by early Spanish explorers may have been the source of occasional palms in the tropical and subtropical regions of the New World from Florida to South America. The fruit was well known in Spain from plantings at Elche and from importations from North Africa. But the Spanish missionaries who followed the early explorers were the first who are known to have planted date seeds in connection with the founding and operation of their many missions. In the damp climate of the West Indies and the

southern Atlantic seaboard the fruit of the date palm does not mature satisfactorily, and the palms attracted little attention, although they were sometimes mentioned in accounts of that region. In a season hotter and drier than normal the fruit of early-ripening seedling palms occasionally matures sufficiently to be utilized along the coast of south Florida and in the Bahamas. In 1899 a small importation of date offshoots or suckers of choice varieties was made to Jamaica from Algeria, but it was subsequently found that the fruit would not mature.

On the western side of the Americas, however, there are climatic conditions more favorable to date culture, and palms grown from seeds planted at missions established in some parts of western Mexico in the late 17th and early 18th centuries bore fruit which reached maturity and was found to be a desirable addition to the native menu. Although the palm population has increased in the original localities and there is some export of fruit to other parts of Mexico, especially from Baja California (San Ignacio, Mulegé and Comondu), date culture is crude and primitive and the fruit is mostly inferior in quality because all the palms are unselected seedlings.

In South America at least one colony of date palms, similar to those in Baja California and traceable to early Spanish settlement, is growing under somewhat less favorable conditions in Peru near Ica. On the island of Santa Margarita off the coast of Venezuela there are said to be date palms from which fruit is sold in the markets of nearby ports along the mainland. In the desert of northwest Argentina and in the more arid portions of northeast Brazil date palms grown from seeds are now being tried with results that indicate some future possibilities for date culture.

FIG. 6. Cutting a date offshoot, showing chisel and sledge hammer in use. (*U.S.D.A. Circular 728*)

FIG. 7. Date offshoots the first year after planting in Algeria. They are wrapped with date leaves for protection against sun and wind during the first summer and against cold during the following winter.

The only serious attempt to establish date culture in the Western Hemisphere has been made in the United States. As early as 1890 the U. S. Dept. of Agriculture arranged through correspondence for a small importation of date offshoots from the Old World, but it was not until 1900 and the years immediately following that planting material of the better varieties was obtained by plant explorers of the Department who visited the date-growing regions of Algeria, Tunisia, Egypt and Iraq (8, 11, 14, 15, 20, 22). In cooperation with the State agricultural experiment stations, experimental plantings were made, first in the Salt River Valley of Arizona and later in the Coachella Valley of California. These experiments attracted the attention of prospective date growers and led to several large commercial importations of offshoots from Algeria and Iraq, which made acreage plantings possible.

Present Status of Date Culture

Table I lists the principal countries of the world in which date palms are grown, with estimates of the number of those palms. The figures for Iraq, Iran, Egypt, French North Africa, the United States and Spain are from recent official sources. Other figures are estimates given in the literature.

Iraq leads the world in date production. About half of its total palm population lies in a continuous line of date gardens along the banks of the Shatt al Arab, the name given to the combined flow of the Tigris and Euphrates rivers from their junction to the Persian Gulf, a distance of over 100 miles (7). This region possesses a combination of unsurpassed natural advantages for date culture, conditions which are shared to some extent by adjoining districts in Persia and Arabia. These three countries combined contain about half of the producing date palms in the world. Dates from Iraq have long dominated world markets. Total exports from Iraq averaged 238,000 short tons for the three years ending in 1948. Exports from Iran for the same period averaged about 34,000 short tons yearly. Exports for the 1949 season were 24,024 short tons from Algeria, 4,374 from Tunisia, and in excess

TABLE I

PRINCIPAL DATE-GROWING COUNTRIES OF THE WORLD

Country	Number of Date Palms in Millions
Iraq	17.7
Arabia	8.0
Algeria	6.9
Iran	6.0
Egypt	5.3
Libya (Tripolitania, Fezzan, Cyrenaica)	3.0
Pakistan (Indus Valley and Baluchistan)	3.0
Morocco	2.9
Tunisia	2.5
Sudan	1.3
United States	.3
Spain	.2
Total	57.1

of 11,000 from Muscat, Arabia. About 2,600 short tons were exported from Tripolitania in 1946, but a ban on exports was imposed the following year because of a general shortage of foodstuffs.

In all the other countries listed in Table I, dates supply the inhabitants and some nearby native populations with an important staple food, but export into world markets is insignificant.

In the United States commercial plantings of dates in 1948 totaled 5,127 acres in southern California and about 550 acres in southern Arizona. In addition, there may have been as much as 100 acres in southwest Texas (Carrizo Springs, Laredo and the Lower Rio Grande Valley), mostly seedling palms in small scattered plantings. Production figures up to 1948, available only for California but representing more than 90 percent of the total for the United States, give a maximum yield of 33 million pounds in 1946.

Ecological Relations

Climate. The date palm will grow in any tropical or subtropical climate where minimum temperatures of 20° F. or below seldom occur, but for satisfactory maturation of its fruit it is necessary to have a long hot growing season and a nearly rainless period while the fruit is ripening. Localities where dates are grown throughout the Northern Hemisphere are compared in Table II as to the average daily maximum air temperature for the growing period, May to October inclusive, the average daily minimum air temperature for January, the average rainfall for the critical ripening period, July to October inclusive, and the annual rainfall.

Basra (Iraq), Dakla (Egypt), Muscat (Arabia) and Touggourt (Algeria) are typical localities where climatic conditions are favorable for date culture. The average daily maximum temperature, May to October inclusive, is well above 95° F., and the rainfall from July to October inclusive is less than one-half inch. Indio, Calif., most nearly approximates these conditions in the United States. However, the average rainfall from July to October, although only .66 inch at Indio, is an index to the frequency of rain damage to ripening fruit, which occurs more than twice as often as at Basra or at Touggourt. Locations bordering large bodies of water have the disadvantage of high relative humidity, but around the Persian Gulf and the Gulf of Oman this is offset in part by low rainfall and high temperatures; furthermore, the best dates are produced at varying distances inland where part of the time they are exposed to hot dry winds from the interior desert, but are not continuously subjected to extremes of either high or low relative humidity.

Average daily maximum temperatures below 90° F. during the growing period are distinctly limiting for date culture, and in localities like Alexandria (Egypt), Gabes (Tunisia) and Elche (Spain) only early-ripening varieties mature. In some instances late-ripening dates may carry through the winter to ripen irregularly the next spring if not prevented by rains.

Localities with rainfall in excess of two inches during the July–October period are also marginal for date culture, but the distribution of this rainfall and the nature of its occurrence have some modifying effects. In most of the localities listed the incidence of rain increases in late fall. Exceptions are Multan (Pakistan) and Phoenix (Arizona) where a considerable part of the year's rainfall occurs in July and August. When summer rains are below normal and later than usual, fruit may ripen before the peak of the rainy season at Multan because of very high temperatures. When summer rains are below normal and earlier than usual, fruit may ripen satisfactorily after the rainy season at

TABLE II

CLIMATIC DATA FOR CRITICAL PERIODS IN COUNTRIES WHERE DATES ARE GROWN*

Station	Latitude N.	Average Daily Air Temperature			Average Rainfall		
		No. yrs. record	Maximum May to Oct. incl.	Minimum Jan.	No. yrs. record	July to Oct. incl.	Annual
Multan, Pakistan	30° 12′	10	102.5	43.3	?	4.75	7.30
Basra, Iraq	30° 34′	19	99.4	43.6	20	0.14	6.42
Muscat, Arabia	23° 37′	18	101.4	60.6	27	0.14	4.17
Alexandria, Egypt	31° 12′	45	83.8	51.1	62	0.28	7.24
Cairo, Egypt	30° 2′	37	92.7	45.7	37	0.08	1.02
Dakla, Egypt	25° 29′	21	99.4	40.6	15	0.00	0.04
Gabes, Tunisia	33° 57′	40	84.7	42.8	10	2.29	7.82
Touggourt, Algeria	33° 9′	15	96.6	38.1	16	0.31	2.27
El Kantara, Algeria	35° 12′	9	88.5	36.5	15	2.28	9.71
Erfoud, Morocco	31° 26′	12	97.5	34.3	12	0.83	2.72
Elche, Spain	38° 16′	6	82.7	44.4	1	7.00	15.9
Indio, Calif.	33° 43′	25	99.7	38.6	53	0.66	3.00
Phoenix, Ariz.	33° 28′	35	96.2	38.7	55	3.07	7.43
Carrizo Springs, Texas	28° 32′	8	94.0	40.4	17	8.93	20.57

*Data from official records of countries named, supplied either direct or through the U. S. Weather Bureau with the exception of that for Multan, Pakistan, which is from Milne and which omits the rainfall for October, probably less than 1 inch and not included in the July-October average.

Phoenix because of somewhat lower temperatures. When rain is preceded and followed by clear dry weather, as often happens in desert regions, it may be possible to protect the fruit from damage, as will be mentioned later. Also, if even a small percentage of fruit can reach the initial stage of final ripening while still on the palm, with some types of dates the fruit can then be harvested and a large proportion of it ripened under artificial conditions off the palm, thus avoiding fall rains or low temperatures, as will also be discussed later.

Soil. Dates are grown on a wide range of soils (1, 7, 19). Soil type may be important for the best production and quality of certain varieties, but it is not a limiting factor in date culture. The maximum water-holding capacity consistent with good drainage is necessary for high production. Without drainage under desert conditions there is a gradual accumulation of salts in the soil which in time become toxic to root growth. Although the date palm will grow in soils containing more alkali or salts than many other plants will tolerate, the best palm growth and fruit quality cannot be obtained under saline soil conditions.

Water Requirements. For maximum growth and fruit production the date palm requires an abundance of water. The Arabs have a proverb that the date palm must have its " feet in water and its head in the fires of heaven ". The largest, oldest and most prosperous date area in the world is that along the banks of the Shatt al Arab in southern Iraq where the gardens are watered twice a day by the tidal action of the Persian Gulf which raises the river water into ditches between the palm rows. The Nile River also supports luxuriant growth and production of date palms along its banks. The finest dates of the Sahara Desert are those grown in oases which receive a continuous and dependable supply of water either by gravity from high bodering mountains, as in some of the Ziban oases of Algeria and in Figuig and Tafilelt in Morocco, or from artesian sources, as in the Oued Rhir oases of Algeria, or in even more remote oases, such as Kufara in the center of the Libyan Desert.

Although fruit production requires an adequate supply of water, the date palm, because of its unique structure, is able to survive long periods of drought. For this reason it is widely grown in desert areas where irregular and erratic supplies of water are insufficient to sustain other fruit trees. For example, along the northern edge of the French Sahara there are oases supplied with water from streams originating in the Atlas Mountains. The amount of water in these streams may be adequate for continuously good production relatively near to the point of emergence from the mountains, but it varies with the rainy cycles. As a consequence the lower reaches of some of these streams may receive little or no water for several years at a time. Nevertheless date palms will usually be found at the farthest point reached by occasional floods. Such palms may make little growth and produce no fruit for several years during a dry cycle, but when a rainy period comes in the mountains they will flower and fruit in proportion to the flood water that reaches them.

In many places palms will be found growing without cultivation. Sometimes they are dependent upon underground seepage which may be barely sufficient to sustain life. Sometimes they are dependent upon rainfall, never adequate in a climate which permits fruiting. A large proportion of the palms growing on the Island of Djerba off the eastern coast of Tunisia are in this second group. Such palms are stunted, many of them appearing as wild native growth; they produce little fruit, most of which is used as stock food, but this fruit and the other prod-

ucts are valued by the natives. Probably no other plant grown under desert conditions contributes so much for so little.

Varieties

Varieties of dates vary greatly in all characters, both vegetative and fruit. They are generally divided into three groups according to whether the flesh of the fruit as it ripens under normal conditions in a favorable climate is soft, semidry or dry. The divisions are somewhat arbitrary, as consistency of flesh is affected more or less by climatic conditions and methods of handling, but the classification is convenient and widely used.

In marginal districts and in many places where dates are all consumed locally, most of the date palms are usually seedlings, but each of the more important date-growing countries or regions in the Old World has evolved its own varieties (3, 5, 7, 11, 12, 18). There are probably not less than 1000 that have been propagated and named, but only a few that have been extensively planted and are found beyond the localities where they originated. In Iraq, Zahidi, a semidry date, is the most widely grown variety, but three soft dates, Sayer, Halawy and Khadrawy, constitute the bulk of the fruit exported from the famous Shatt al Arab district. In Egypt the Hayany is the most extensively planted variety in the densely populated Nile delta, but it is a very soft date which is not exported; the Saidy, a soft date, is the most important variety in the Libyan Desert. In Algeria and Tunisia, Deglet Noor, a semidry date, is the only variety grown primarily for export. In Morocco there was formerly some export of the Medjool, a soft date, but in recent years production has been seriously curtailed by the dread bayoud disease. All the varieties named, as well as some others of promise, have been introduced into the United States, but the Deglet Noor is the principal variety now grown and it comprises about 75 percent of the total date acreage in this country. The dry dates, also known as "bread" dates, although popular among the natives of the Old World, have not found much favor among European and American consumers; one variety, the Thoory from Algeria, is grown to a very limited extent in California.

Composition of Dates

The dry flesh of the ripe date is composed of about 75 to 80 percent sugar. In most varieties, including nearly all the soft dates, this sugar is almost entirely of the invert type (glucose and fructose). In some dry and semidry varieties, of which Thoory and Deglet Noor, respectively, are outstanding examples, there is a relatively high proportion of cane sugar (sucrose).

The flesh of dates with a moisture content of 20 percent contains 60 to 65 percent of sugar, about 2.5 percent of fibre, two percent of protein, and somewhat less than two percent each of fat, mineral matter and pectic substances. Such fruit will furnish about 1,430 calories per pound. The nutritionally important elements in the mineral constituents are present in sufficient amounts to classify the date as a good source of iron and potassium, a fair source of calcium, and a poor source of phosphorus. There are also moderate amounts of chlorine, copper, magnesium and sulfur. Dates have been found to contain small amounts of vitamin A and of vitamins B_1 and B_2, and are a good source of

FIG. 8. Pollination of date flowers in California. Strands of male flowers are being placed in the center of the female cluster. A freshly opened spathe, ready for pollination, is seen in the foreground and above it a flower cluster after pollination. Twine is tied around the strands to hold the male flowers in place and to prevent tangling in leaves. (*U.S.D.A. Circular 728*).

nicotinic acid, but they contain only negligible quantities of other vitamins.

Cultural Methods

Propagation. Dates may be grown either from seeds or from offshoots. When grown from seeds, approximately half of the palms will be male and produce only pollen. No two seedling palms are alike, and relatively few of them are likely to produce fruit of good quality. However, when a seedling palm appears outstanding in any way, it can be propagated by its offshoots which will always reproduce the parent type. New varieties, or clones, originate in this way. Bud variation, or sectorial mutation, has been observed in the date palm, but apparently it is very rare.

Since the date palm cannot be budded or grafted, propagation of varieties is exclusively by offshoots which develop from axillary buds on the trunk chiefly during the early life of the palm. After three to five years of attachment to the parent palm, offshoots in contact with moist soil will usually have produced roots, and they are then ready to be removed. Rooting of offshoots slightly above the soil surface is encouraged by mounding up the soil. Soil may be held around the base of high offshoots by means of boxes, but unless such offshoots are very valuable they are more often either discarded or allowed to become quite mature on the palm and then placed in a nursery where some of them will usually root.

In removing offshoots the soil is first dug away around the base so as to expose the connection which is then cut with a large long-handled chisel.

Planting. Before planting the offshoot, the lower and outer leaves are removed, and a few of the higher and inner leaves, which are cut back two to four feet above the base, are retained. Offshoots are usually planted in basins or borders four to six feet across and six to 12 inches deep to facilitate irrigation. For protection against sun and wind the first summer and against cold the following winter, the newly planted offshoot is often wrapped with a layer of date leaves, date fibre, coarse grass, or, sometimes in the United States, burlap.

The preferred spacing for dates is nine by nine metres in the French plantations of Algeria or 30×30 feet (48 per acre) in the United States. In most of the native plantings of the Old World they are planted much closer. Dowson estimated the average density of palms along the Shatt al Arab at about 125 per acre, and later from experimental plantings near Basra he found that a spacing of 100 to 120 per acre was actually better under conditions there because of hot and violent summer winds. Under conditions marginal for date culture because of low temperature and high humidity at Gabes (Tunisia) and Elche (Spain), dates are planted ten to 15 feet apart in single or double rows around rectangular plots of varying size, in the centers of which are grown cereals, vegetables or low fruit trees. This arrangement affords maximum exposure of one or both sides of the palm rows to sunlight and aeration.

Irrigation. In discussing the water requirements of the date palm it was mentioned that along the Shatt al Arab in southern Iraq date gardens are watered from below upward. A water table within about six feet of the surface, if not too saline, will support fair palm growth and fruiting in proportion to the quality of the water and the character of the soil, although prolonged immersion of all the roots in stagnant water will in time cause death of the palm. Dates are grown without surface irrigation, with sub-surface water at about five feet below the level of the gardens among the sand dunes of Algeria's Oued Souf, although offshoots are set in the bottom of holes deep enough to place the base within

about 18 inches of the water level and must be irrigated the first season until roots have reached the water.

In most places where dates are grown, however, surface applications of water during winter. Experience on relatively light soils in Coachella Valley, Calif., indicates that not less than nine acre-feet of water per year is necessary for maximum yield of palms in full produc-

FIG. 9. Harvesting Deglet Noor dates from a high palm in a California date garden. The laborer climbs to the crown with a ladder, then uses a belt and chain for support while picking the fruit. When a bucket is filled, it is lowered to the ground with a rope. (*U.S.D.A. Circular 728*).

are necessary. Light frequent irrigations are required for offshoots the first season and until well established. Bearing gardens on the lighter soils are usually irrigated every seven to 14 days during midsummer and every 20 to 30 days tion, and that from 12 to 18 acre-inches per month is required during summer. Half that amount may be sufficient on heavy soils.

Fertilization. Fertilization has generally been found necessary to maintain

quantity and quality of production on a high level, but there are few experimental data bearing on the kind and quantity of fertilizer or on the time of application. Animal manures are widely used in the better date gardens. In addition, some supplementary nitrogen in an inorganic form is also applied in many gardens in California and Arizona, and complete inorganic fertilizer in the French gardens of Algeria. Cover crops are sometimes grown until the palms reach full production, when with the usual commercial spacing there is too much shade. The old date leaf and fruitstalk prunings are being returned to the soil by some growers in California who use mechanical choppers to cut them into small pieces.

Pruning. Pruning of date palms in commercial production is generally confined to the removal of dead or partially dead leaves. In localities in the Old World where there is considerable demand for date leaves for use in various by-products, green leaves may be taken from male palms and inferior seedlings. With some varieties it may be necessary occasionally to remove a few green leaves to facilitate the handling of bunches. In California it has been found that healthy palms of the Deglet Noor variety just coming into full bearing after several years of favorable growing conditions may retain more green leaves than are necessary for the best quality and quantity of fruit, and removal of green leaves in excess of about 120 per palm has been beneficial; but such conditions are rarely found in the Old World where more often the normal complement of leaves, which varies somewhat among different varieties, is less than that required for maximum fruit production.

In Lower Egypt, contrary to the practice prevailing elsewhere, date palms are pruned very high, all but 40 or 50 green leaves in the center of the crown being removed. In addition to a strong demand for leaf midribs for crate making, two other reasons for the practice are given, both of which are consequences of the low maximum temperatures and the relatively high humidity of the Nile Delta. All leaves are affected by a fungal leaf spot (*Graphiola*) which causes early death of the green tissue, and removal of the older and badly infected leaves is believed to be beneficial. Fruit ripening is said to be promoted by full exposure of the bunches to sunlight which results from high pruning.

In California and Arizona spines are removed from all leaves to facilitate pollination and subsequent handling of bunches. In the Old World this is done in some localities but not in others.

Pollination. One of the unique and distinctive operations in date culture is artificial pollination. It is a very ancient practice which had already been evolved by the time of Hammurabi. Apparently the Sumerians at an early date saw the economy of reducing the number of cultivated palms in this way. Water is at a premium under desert conditions, and, instead of approximately equal numbers of palms of both sexes, which obtains when seeds are planted, one male palm will suffice for 50 or more female palms if the pollen is conserved and applied by hand. There are Assyrian bas-reliefs which appear to represent pollination of the date palm, although the pictures are highly stylized and authorities are not entirely agreed as to their interpretation.

The most common method of pollination is to cut the strands of male flowers from a freshly opened inflorescence and insert two or three of them among the strands of the female flower cluster dur-

FIG. 10. Harvesting Deglet Noor dates in Algeria. After nearly all the fruit is ripe the entire bunch is cut and lowered to the ground by a human chain of laborers spaced at intervals along the trunk.

FIG. 11. A picking belt in use near Bagdad, Iraq.

ing the first two or three days after it has opened. In some parts of the Old World the strands of male flowers are simply left wedged crosswise among the strands of the female cluster; in others the male strands are inverted and held in place among the female strands by a strip torn from a nearby leaflet and tied around the female cluster. In the United States twine is tied around the pollinated cluster, not only to hold the male flowers in place but also to prevent the strands of the female cluster from becoming entangled in the leaves during the rapid growth which follows. To provide for expansion of the cluster as the fruit develops, the twine is commonly tied in a slipknot having the free end long enough to permit later adjustment to the maximum size of the bunch. In the United States pollen is also dried and applied either on small pieces of cotton or with insect dusters. Dry pollen, protected from extreme heat, remains viable for two or three months; and if stored in a sealed container and placed in cold storage it may be held from one season to the next.

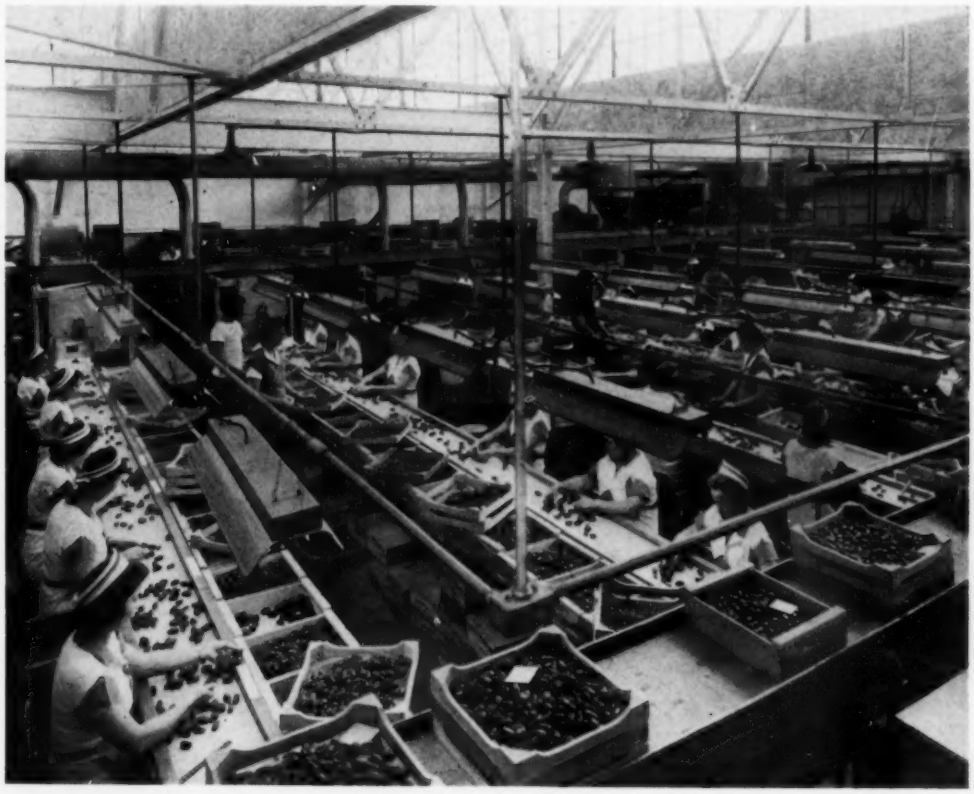

FIG. 12. Grading dates in a modern date packing house in California. (*Photo by Field Studios*)

Fruit Thinning. Without fruit thinning date palms tend to bear only in alternate years. In most parts of the Old World fruit thinning is confined to removal of entire bunches, depending on the size, vigor and variety of the palm. In California and Arizona a few bunches are removed, but better results have been

FIG. 13 (*Upper*). Grading Deglet Noor dates from a large French garden in the Oued Rhir of Algeria. Most of the fruit is sent to packing houses in Marseilles, France, to be regraded and prepared for market.

FIG. 14 (*Lower*). Grading dates in a native garden at Mandali, Iraq.

obtained by reducing the size of all the the bunches retained. A total of from one-half to three-fourths of the flowers or fruits on each bunch is removed. This thinning is done by cutting back the tips of all strands at time of pollination and by cutting out entirely some of the strands from the center of the bunch a few weeks later. With varieties whose inflorescences have short strands, most of the thinning is done by removing entire strands. With varieties whose inflorescences have long strands, more thinning is done by cutting back the tips

FIG. 15 (*Upper*). A basket being made from date leaflets at Mandali, Iraq.
FIG. 16 (*Lower*). Brooms made from date leaves at Mandali, Iraq.

FIG. 17. Cord being made from date fiber which encircles the trunk at the base of the leaves. Touggourt, Algeria.

of strands and less by removing entire strands. Reducing the number of fruits on the bunch increases the size, improves the quality and prevents delayed ripening of the fruit; it also reduces the weight and compactness of the bunch, thus facilitating picking and providing better aeration of the bunch during periods of high humidity.

Fruit Protection. In many localities it is necessary or desirable to protect the fruit on the palm from birds, insects, wind or rain. Different materials and methods are used in different places. Covers of matting are used to protect fruit bunches from birds in the Punjab (Pakistan). In the Nile Valley of Egypt nets are put over the bunches of certain varieties to keep off birds and bats. In the Libyan Desert a layer of thorny material (camel's-thorn) is placed around bunches to protect them from wind. Early-ripening soft dates in California and Arizona are often covered with light porous cloth or netting as protection against birds and insects; late-ripening dates, like the Deglet Noor, are covered with paper tubes attached to the fruit stalk immediately above the bunch as protection primarily against rain and secondarily against birds.

Harvesting. Although the fruit from rare palms and much of what is consumed locally early in the season may be picked singly from the bunches, the main date crop in the principal date countries of the Old World is harvested by cutting the bunches after all, or nearly all, the fruit is ripe. If the fruit is well cured, or of the dry type, and the palms are not exceedingly high, the bunches may be dropped to the ground. If the fruit is very soft and likely to be injured, the bunches are lowered from high palms by means of trays or a hook made of a v-shaped piece of wood, as in Iraq, or passed by hand along a human chain of laborers spaced at intervals along the trunk of the palm from the crown to the ground, as in French North Africa.

In the United States most dates are picked singly from the bunch, and several pickings are usually required to harvest the fruit during a season which lasts three or four weeks for early varieties and two to three months for late varieties. Dry dates like Thoory are left until all the fruit is fully ripe and then the entire bunch is cut. With the semidry variety, Zahidi, entire bunches are also sometimes cut after all the fruit is ripe.

Artificial Maturation

The changes associated with ripening and the period during which date fruit may be consumed extend from the peak of the khalal stage, when the fruit has its most intense red or yellow color and maximum weight, to the final tamar stage, when it has lost the greater part of its moisture and will keep without special attention to storage. Arabs eat large quantities of dates of many varieties in the khalal stage. With very few exceptions dates are quite astringent in the khalal stage and do not appeal to the European or American palate. Many people find dates very appetizing in the

rutab stage, which is between the khalal and the tamar, while the fruit is still plump and the moisture content high. Fruit in this condition is difficult to handle, and if it is to be marketed it must be either consumed immediately or placed in storage at a very low temperature. Consequently most of the dates that are exported from the date-growing countries or held there as a year-round staple represent the cured, or tamar, stage.

FIG. 18. Crates made from the midribs of date leaves and used for shipments of offshoots from Iraq to the United States.

In an ideal date climate, such as that of Iraq and much of the Sahara Desert, where the average maximum temperature is sufficiently high and where there is normally no rain during the ripening period, dates left on the palm cure naturally. On the other hand, there are many places where date palms grow well but the climate is marginal for fruit production. In some, such as the Indus Valley of Pakistan and the Salt River Valley of Arizona, the heat is sufficient but rain during the ripening season interferes with maturation of the fruit. In others, such as the Nile Delta near the Mediterranean in Egypt, the ripening period is nearly rainless but maximum temperatures are insufficient for proper maturation of the fruit. In some instances, of course, both factors may limit but not entirely prohibit cultivation of dates. Date culture is partially adjusted to these conditions in two ways: by selection of varieties whose time of ripening does not coincide with the rainy season, and by harvesting the

fruit in the khalal or early rutab stage and completing the ripening and curing by artificial means off the palms. Ripening off the palm is possible because most dates at the peak of the khalal stage have already acquired their maximum sugar content (21). Further ripening has to do primarily with a change of tannin from soluble to insoluble form, with breakdown or softening of cellular and fibrous material, and with formation or liberation of certain esters concerned in fruit flavor.

Date varieties vary greatly as to the conditions necessary to bring about these changes. Some, like the Hayany, which is grown most extensively in the cool Delta region of Egypt, complete the ripening process at relatively low temperatures. Because of this and the fact that it is much easier to handle the fruit before it begins to soften, practically the entire crop of the Hayany variety in Egypt is harvested and marketed at the peak of the khalal stage while it is still hard and deep red. If the consumer prefers, he may hold the khalal fruit for a few days, and at the temperatures usually prevailing it will soften and lose its astringency without special attention. The Saidy date, on the other hand, requires more heat to complete its maturation, and, as it is grown in Lower Egypt, it is harvested in the late khalal stage and spread out upon matting in drying yards so arranged as to afford maximum exposure to sunlight in order to promote further maturation and curing for a period of 12 to 14 days.

At Elche, in southeastern Spain, use is made of acetic acid to promote ripening of the khalal fruit of some seedling dates grown in that district. According to a demonstration witnessed by the writer, about 20 pounds of khalal dates are placed in a large bowl with a cupful of vinegar. The fruit is stirred by hand until all of it has come in contact with the vinegar; then the vinegar is poured off and the dates are placed in a barrel or box, the bottom of which is lined with green date leaflets. The process is repeated until the container is nearly full. Then a piece of cloth is placed over the top of the fruit, and on top of that some stones or heavy material. After a few hours to a few days, according to the season and the character of the fruit, the dates lose their astringency, begin to soften and become palatable.

In the United States supplementary maturation is accomplished in special rooms or chambers where uniform temperatures can be maintained by artificial heat. By providing also means for controlling the relative humidity, the softening and drying processes can be varied according to variety, maturity and weather conditions. In Salt River Valley, Arizona, most varieties are picked when the tip of the fruit first softens a little, and further ripening is completed in maturation rooms. In Coachella Valley, California, most of the ripening is completed on the palms, and maturation roms are used mostly for very late-ripening fruit or in occasional wet years when the fruit must be picked early to avoid losses on the palm. The drier grades of semidry varieties, such as Deglet Noor and Zahidi, are softened for market by special processes in which the fruit is exposed to steam vapor (hydration). Widespread use of cold storage in the United States has made it possible to hold dates with a higher moisture content than would otherwise be possible.

Fruit Handling

Dates for European and American markets are handled in modern packing houses where they are fumigated, cleaned, graded and given such supplementary treatments and packaging as may be needed to meet the demands of discriminating consumers. Dates from French plantations in Algeria are graded there, and most of the crop is then

shipped to packing houses in Marseilles for subsequent handling. Dates imported from Iraq to the United States go through much the same procedure, final packaging being done in this country. In California and Arizona all operations subsequent to picking, including supplementary maturation and hydration as mentioned above, are carried out in packing houses located mostly in the districts where the fruit is grown.

Enemies

The bayoud disease, attributed to a fungus (*Fusarium albedinis* (Killian & R. Maire) Malençon), is the most serious disease affecting the date palm (9). At present it occurs only in the date-growing areas of Morocco and in certain oases along the western border of Algeria, but it is a potential menace to other date-growing areas of the world. It is characterized by a progressive and rapid blanching and wilting of the leaves followed by death of the palm, sometimes within two months. It probably spreads chiefly through the soil but is believed to have been carried long distances by man in transportation of offshoots and woody parts of the palm in which the fungus may survive for months. Efforts are being made to check further spread of the bayoud by a quarantine against movement of date offshoots and palm parts from the diseased areas. There is no known remedy for the disease.

Other diseases to which the date palm is susceptible seldom cause serious losses. Khamedj is a fungus disease which occasionally attacks and destroys immature inflorescences in north Africa. In the same region the bending head, or " la tête qui penche ", a disease of unknown cause, is responsible for the death of occasional palms. Black scorch is a widespread fungus disease, in both the Old World and the New; it stunts and distorts young leaves and inflorescences and may sometimes cause a bud rot, but it is of rare occurrence and palms usually recover. Graphiola leaf spot is a fungus disease of world-wide distribution which attacks date leaves and may be responsible for their early death in humid regions, but it is absent or unimportant in localities where the relative humidity is low.

FIG. 19. A date leaf used for Palm Sunday celebration at Elche, Spain. On this occasion nearly every family in Spain will have one or more date leaves, or sections thereof, with the leaflets often woven into various ornamental designs. These leaves are cut only from male palms, and the revenue derived from them compensates in part for the fact that about half of the date palms in Spain are males because all of them have been grown from seeds.

Fruit rots due to several different fungi may cause considerable loss when humid weather occurs during the ripening season. Blacknose and checking are

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Date varieties vary greatly as to the conditions necessary to bring about these changes. Some, like the Hayany, which is grown most extensively in the cool Delta region of Egypt, complete the ripening process at relatively low temperatures. Because of this and the fact that it is much easier to handle the fruit before it begins to soften, practically the entire crop of the Hayany variety in Egypt is harvested and marketed at the peak of the khalal stage while it is still hard and deep red. If the consumer prefers, he may hold the khalal fruit for a few days, and at the temperatures usually prevailing it will soften and lose its astringency without special attention. The Saidy date, on the other hand, requires more heat to complete its maturation, and, as it is grown in Lower Egypt, it is harvested in the late khalal stage and spread out upon matting in drying yards so arranged as to afford maximum exposure to sunlight in order to promote further maturation and curing for a period of 12 to 14 days.

At Elche, in southeastern Spain, use is made of acetic acid to promote ripening of the khalal fruit of some seedling dates grown in that district. According to a demonstration witnessed by the writer, about 20 pounds of khalal dates are placed in a large bowl with a cupful of vinegar. The fruit is stirred by hand until all of it has come in contact with the vinegar; then the vinegar is poured off and the dates are placed in a barrel or box, the bottom of which is lined with green date leaflets. The process is repeated until the container is nearly full. Then a piece of cloth is placed over the top of the fruit, and on top of that some stones or heavy material. After a few hours to a few days, according to the season and the character of the fruit, the dates lose their astringency, begin to soften and become palatable.

In the United States supplementary maturation is accomplished in special rooms or chambers where uniform temperatures can be maintained by artificial heat. By providing also means for controlling the relative humidity, the softening and drying processes can be varied according to variety, maturity and weather conditions. In Salt River Valley, Arizona, most varieties are picked when the tip of the fruit first softens a little, and further ripening is completed in maturation rooms. In Coachella Valley, California, most of the ripening is completed on the palms, and maturation roms are used mostly for very late-ripening fruit or in occasional wet years when the fruit must be picked early to avoid losses on the palm. The drier grades of semidry varieties, such as Deglet Noor and Zahidi, are softened for market by special processes in which the fruit is exposed to steam vapor (hydration). Widespread use of cold storage in the United States has made it possible to hold dates with a higher moisture content than would otherwise be possible.

Fruit Handling

Dates for European and American markets are handled in modern packing houses where they are fumigated, cleaned, graded and given such supplementary treatments and packaging as may be needed to meet the demands of discriminating consumers. Dates from French plantations in Algeria are graded there, and most of the crop is then

shipped to packing houses in Marseilles for subsequent handling. Dates imported from Iraq to the United States go through much the same procedure, final packaging being done in this country. In California and Arizona all operations subsequent to picking, including supplementary maturation and hydration as mentioned above, are carried out in packing houses located mostly in the districts where the fruit is grown.

Enemies

The bayoud disease, attributed to a fungus (*Fusarium albedinis* (Killian & R. Maire) Malençon), is the most serious disease affecting the date palm (9). At present it occurs only in the date-growing areas of Morocco and in certain oases along the western border of Algeria, but it is a potential menace to other date-growing areas of the world. It is characterized by a progressive and rapid blanching and wilting of the leaves followed by death of the palm, sometimes within two months. It probably spreads chiefly through the soil but is believed to have been carried long distances by man in transportation of offshoots and woody parts of the palm in which the fungus may survive for months. Efforts are being made to check further spread of the bayoud by a quarantine against movement of date offshoots and palm parts from the diseased areas. There is no known remedy for the disease.

Other diseases to which the date palm is susceptible seldom cause serious losses. Khamedj is a fungus disease which occasionally attacks and destroys immature inflorescences in north Africa. In the same region the bending head, or " la tête qui penche ", a disease of unknown cause, is responsible for the death of occasional palms. Black scorch is a widespread fungus disease, in both the Old World and the New; it stunts and distorts young leaves and inflorescences and may sometimes cause a bud rot, but it is of rare occurrence and palms usually recover. Graphiola leaf spot is a fungus disease of world-wide distribution which attacks date leaves and may be responsible for their early death in humid regions, but it is absent or unimportant in localities where the relative humidity is low.

FIG. 19. A date leaf used for Palm Sunday celebration at Elche, Spain. On this occasion nearly every family in Spain will have one or more date leaves, or sections thereof, with the leaflets often woven into various ornamental designs. These leaves are cut only from male palms, and the revenue derived from them compensates in part for the fact that about half of the date palms in Spain are males because all of them have been grown from seeds.

Fruit rots due to several different fungi may cause considerable loss when humid weather occurs during the ripening season. Blacknose and checking are

physiological diseases of the fruit caused by humid weather immediately preceding the khalal stage.

Although the date palm has some enemies which in certain localities may occasionally be more destructive, the most serious perennial pest in the principal date-growing countries of the world is the date mite.[2] It is of no importance in marginal areas where the relative humidity is high. The date mite causes drying and scarring of the fruit surface and is often responsible for a large percentage of culls and low-grade fruit, but it may be easily controlled by sulfur dust aplied one or more times after the fruit begins to size up in late spring and early summer.

Two scale insects occur on date palms in the principal date-growing areas of the Old World. Parlatoria (*Parlatoria blanchardii* Targ.) is usually held in check by certain parasites and seldom causes serious damage except on certain varieties in the drier and more exposed situations. This scale was introduced into the United States on early importations of offshoots and for a time seemed to threaten the future of the industry, but it is now believed to have been completely eradicated by Federal and State agencies. The red date scale (*Phoenicoccus marlatti* Ckll.) attracts little attention, as it is found mostly underneath the fiber behind overlapping leaf bases, around the bases of fruitstalks and not infrequently on roots underground; but it seldom appears to cause appreciable damage to palms growing under favorable conditions. The red date scale is present in the commercial date gardens of California and Arizona.

In Iraq several Tineid moths of the family Gelechiidae attack the fruit in the early stages of development, causing it to drop and resulting in considerable losses each year.

Several small fruit beetles of the cosmopolitan family Nitidulidae sometimes cause considerable damage to ripening dates in California and Arizona, particularly during damp weather. These and other widespread insect pests, such as the Indian-meal moth (*Plodia interpunctella* Hbn.), make fumigation and careful storage of harvested dates necessary.

[2] While formerly regarded as one species, McGregor (16) has separated the American date mite (*Paratetranychus simplex* Banks) from the Old World date mite (*P. afrasiaticus* McGregor).

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Utilization Abstract

Lemongrass Oil. In 1935 a project was undertaken at the Federal Experiment Station in Puerto Rico to investigate some of the crops from which commercially important essential oils are obtained, and a report has been issued with respect to lemongrass oil. The details of this Bulletin are concerned with the culture and processing of this grass, and the more general information may be abstracted as follows.

Lemongrass has been found growing wild in many tropical areas, *e.g.*, the Malabar Coast of India, Ceylon, Malaya, French Indo-China, West Indies, Central and South America, and in parts of Africa. The plant seldom flowers, and distillation of it was recorded as early as the beginning of the seventeenth century in the Philippine Islands. The species originated probably in India; it was introduced into Jamaica in 1799 and later into other parts of the Americas and into Africa. Only cultivated grass is now used for oil production. Two species are involved. *Cymbopogon flexuosus* produces East Indian oil; *C. citratus*, West Indian oil. The former is the principal type produced, but both types contain about 75% citral, the principal ingredient and the one that makes the oil valuable. Citral is separated from the oil for use in the manufacture of ionone, the synthetic violet of the perfume trade. It also has other uses in the synthetic chemical industry. The oil is used as such also in perfuming inexpensive soaps and as a flavoring agent. Secondary uses of the oil, of the plant as a whole and of the roots are also recorded.

Before World War II the annual world production of lemongrass oil was 300 to 350 tons, and the United States imported the oil from Madagascar, Malabar, Travancore, Cochin, Ceylon and Java. Since 1930 sources have been developed in the Western Hemisphere, some of them in Florida where 35,000 pounds of the oil were produced in 1943–44. In 1944, 185,000 pounds were exported from Guatemala to the United States. (M. A. Jones & N. G. Arrillaga, *U. S. Dept. Agr., Fed. Exp. Sta., Mayaguez, P. R., Bull. 50. 1950*).

Sweet Corn—*Mutant or Historic Species?*

The generally accepted viewpoint that sweet corn has been handed down through the ages by the American Indians from pre-Columbian times is challenged in this article regarding it as a mutation of dent corn which may occur at any time and anywhere that extensive areas of field corn exist.

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"If we find it to be true that there are mutations of different genes, then we must assuredly represent these facts in nomenclature".—L. H. Bailey

Sweet corn has been designated as an agricultural species, *Zea saccharata*, by Sturtevant, and as a distinct species, *Z. rugosa*, by Bonafice. Subsequently *rugosa* was reduced to a sub-species of *Zea Mays* by Bailey. In the following discussion *rugosa* is treated as a mutation of *indentata* with the evidence in support of this point of view, and the name *Zea Mays* L. var. *indentata* (Sturt.) Bailey mut. *rugosa* (Bonaf.) Erwin is proposed.

In passing, the fact should be noted that flavor is not a taxonomic character, though so treated in some of the literature. In certain areas of the South, where the corn ear worm devastates sweet corn, field corn is extensively used for roasting ears and is advertised as fresh sweet corn.

What Is Sweet Corn?

Physiologically sweet corn is a form of maize which is incapable of completing the formation of normal corn starch, or, as has been expressed tersely, sweet corn is field corn in an arrested state of development.

Where Did We Get Our Sweet Corn?

Is sweet corn a historic form of maize, an entity which has come down through the ages, harking back to the pre-Columbian era, or is it simply a mutation of field corn which may occur at any time and in any place where field corn is grown extensively?

The historic point of view is widely presented in the literature. In support thereof Papoon corn, mentioned by Sturtevant (6), has been cited. This variety, according to a legend reported in a Plymouth, Massachusetts, newspaper by an anonymous author under the nom de plume of Plymotheus, came from the Susquehanna Valley in New York. It is supposed to have been taken from there to Massachusetts by a Lieutenant Bagnal, a member of Sullivan's Expedition against the Iroquois.

Thus Tapley et al. (7) credit Papoon corn as "the forerunner of other varieties which came from the same or other Indian sources". Likewise Hedrick (3), in his recent volume, attributes to Bagnal the introduction of sweet corn from the Iroquois and other Indian tribes. Carter (1) also lends support to this point of view.

However, Jefferson's Garden Book (1810) mentions "shriveled corn" which is obviously sweet corn. This reference antedates Plymotheus (1822) by more than a decade. If the historical concept is to be accepted, where did Jefferson's seed come from, or was it simply a mutation of local origin?

The fact that sweet corn is a mutation

does not preclude the possibility of its being handed down to us from prehistoric times. However, we think the weight of evidence is against this point of view. Why would the Indian, who often faced the starvation line, grow sweet corn when field corn would give anywhere from a third to a half greater yield?

Moreover, sweet corn is a weakling. Of all the different types of maize, sweet corn is the least able to withstand hardships. It is, for example, more susceptible to inroads from pathogens, such as Stewart's wilt, corn smut and numerous ear fungi, than is field corn. The commercial canners in the corn belt usually plant sweet corn ten days or more later than field corn, as the seed rots rather readily in a cold wet soil.

Likewise sweet corn is more subject to insect injury than field corn. Infestations of the corn ear worm and the stalk borer are generally more pronounced in sweet corn than in field corn.

In brief, it is the weakling of the maize group and ill adapted to the rigors of an Indian agriculture.

It is difficult to maintain a pure strain of sweet corn wherever field corn is grown extensively even when isolated. In the corn belt, for example, sweet corn seed is supplied from growers in isolated regions of Idaho and other sections, at a considerable expense, for this reason. Plymotheus reports this same difficulty, for he states that in a few years it tended to lose "much of its peculiar qualities of softness and sweetness".

Jacques Cartier, the first European explorer to enter the valley of the St. Lawrence, reports observing large fields of maize at Hochelaga (now Montreal) in 1534. However, this corn was evidently of the flint type, for this is the only kind represented in Sturtevant's northern collection of Indian corn.

Sullivan's diary reports extensive destruction of stored Indian corn along the Susquehanna. Field corn was evidently an extensive crop in the New England area, and hence there would have been the same problem of contamination in maintaining a pure strain of sweet corn.

One also wonders who grew Papoon corn and maintained its purity for upwards of half a century intervening between the time of Sullivan's Expedition (1779) and Plymotheus's first report (1822). However, Sullivan does not mention sweet corn.

Plymotheus makes special mention of the red core (cob) and recites the fact that in a few generations he eliminated this fault. If this variety had been grown previously for decades by the white man, would not this fault have been eliminated earlier?

This corn grown by Plymotheus was undoubtedly sweet corn. If his seed did not come from the Iroquois, what was its source? The answer, though wholly speculative, seems simple. Could it not have been an unrecognized mutation originating at hand? The red cob, typical of newly developed mutations of dent corn, is highly suggestive of its recent origin.

In a survey made by the writer, covering the archeological collections of maize in the leading museums of the United States, only a single ear of sweet corn was identified (2). The absence of sweet corn from these numerous collections of maize of the pre-Columbian period is significant.

Shriveled corn, as it was first called, does not appear in the literature until upwards of 100 years after the first settlement, though in the intervening period the maize plant was receiving much attention, particularly in the New England states.

Sturtevant has been widely quoted, even in recent literature, in support of the historic origin of sweet corn. The fact should be noted, however, that in his later studies he questioned its his-

toric origin as being authentic (5): "The origin [of Papoon corn] as stated may be questioned. I suspect that a fuller study *may unite sweet as forms of pops, flints, and dents*". (The italics are the writer's). Thus Sturtevant caught a glimpse of a genetic concept which was verified decades later.

Sweet Corn a Mutant

Important studies of the maize plant by students in the field of genetics necessitate a reorientation of our point of view regarding the origin and taxonomy of sweet corn. Genetic studies have determined that the absence of this starch-forming character, which characterizes the sweet corn group, is a heritable mutation. Dr. E. W. Lindstrom (4) discovered a single kernel of sweet corn as a mutant in a controlled series of pedigree cultures of dent corn. Four generations of this mutant have been crossed with normal sweet corn, and all have proven the original kernel to have been a true mutant of field corn.

Likewise Dr. Stuart Smith * has discovered three proven mutations from starchy to sugary kernels during the past 20 years in hand-pollinated stocks of maize on his plots at Ames. He now has under observation a fourth case which appears to be a mutation from starchy to sugary. All four have been in lines of yellow dent maize. The first one observed was in a line R15 at about the tenth year of inbreeding. This inbred was developed out of open-pollinated Reid Yellow Dent by the Lancaster inbred, LDG. The second observed case was out of the inbred IK19. Its ancestry is from a single cross of IDT by K187. It occurred in the eighth generation of inbreeding. The third case occurred in the inbred line, KRR, in the fifteenth generation of inbreeding. This inbred is out of a variety of Kansas Reid Yellow Dent. The fourth case now under observation as a possible mutant occurred in the inbred line MID721 out of Midland Yellow Dent from Missouri in the seventh generation of inbreeding. Plant and ear type are identical with the starchy non-mutant form in each case. The only alteration appears to be in the presence of the sugary gene which makes typical sweet corn kernels. Crosses are now being made between the sugary and starchy forms to determine the effect of endosperm on embryo development.

Approximately 50,000 hand-pollinated ears have been handled yearly by Smith during the past 20 years. Assuming there were 500 kernels per ear, this would be approximately 500 million kernels. Of course, not every individual kernel might have been detected if there had been a mutation, but there were observed four in this number; so the observed mutation rate would be approximately one in 125 million kernels. There may have been others which escaped observation in the population.

Shortly after the War Between the States, S. S. Barr, an astute student of maize residing near Davenport, Iowa, introduced two varieties of sweet corn, Silver Sweet and Pharaoh's Dream, which he described as sports of Silver Mine field corn. Barr lacked the genetic technique to verify his work, but his concepts were sound. He also attempted to set up certain cultural controls which would induce sweet corn mutations; in this he was obviously unsuccessful.

If we accept sweet corn as a mutation of field corn, then, of course, no one area can be named as the home of sweet corn; mutations simply occur now and then wherever field corn is grown extensively. The great majority of them go unrecognized and are simply regarded as contaminations. Due to the millions of kernels involved, it seems possible for sweet corn mutations to occur in some sections of the corn belt at infrequent intervals

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and disappear again as suddenly as they came.

Introduction of Varieties

Time is an important factor in the development of numerous varieties of a given form. The absence of varietal names is evidence of the youthfulness of a given type. In the first mention of sweet corn in the literature, Jefferson (1810), it is simply designated as shriveled corn. The first named varieties appeared around 1850. Tapley et al. (7) in 1934 listed 956 varieties of white sweet corn, and today the total of former and current varieties far exceeds 1000.

The history of the early introductions bears witness to the enthusiasm of the disseminators and exceeds the claims of the novelty page of a current seed catalogue.

Old Colony. This variety appears to be the first named sort offered in the seed trade. It was introduced in 1850 by Rev. A. R. Pope who evinced an unbounded enthusiasm for this new corn. It yielded six ears to the stalk, he claimed. Pope stated that it was a cross between sweet corn and southern field corn. The southern field corn was obviously dent corn, and in the light of present-day genetics he likely was dealing with a sweet mutation of dent corn.

Papoon Corn. This variety has been widely quoted as the historic source of sweet corn. The first reference to it in the literature is found in the *Old Colonial*, a local newspaper published at Plymouth, Massachusetts, in 1822. The article was written by one who styled himself Plymotheus. According to the legend he recites, the seed came from the Iroquois Indians decades before. Sturtevant (6) in his earlier writings gave support to this point of view. The fact seems to have been overlooked that his later studies caused him to question its accuracy, as indicated by the following significant comment, "The origin as stated may be questioned" (5). It seems probable that Plymotheus was dealing with an unrecognized local mutation of field corn.

Stowell's Evergreen. Stowell's Evergreen was for many decades the most widely grown variety of sweet corn in the United States. It was developed by a truck gardener named Nathan Stowell who resided at Burlington, New Jersey. In the United States Patent Office Reports of 1853 it is referred to as Stowell Sweet and Stowell Late Green. The latter term became shortened to the present name. It was introduced to the trade by Grant Thorburn in 1861.

Like the Old Colony, it was claimed to be a hybrid. The parents were said to be Menomony soft corn crossed with northern sugar corn. Strong claims indeed were made for this rival of Old Colony. Editor Mapes of *The Working Farmer* (1850) reported that if the stalks were placed in a cool dry place . . . the grains would remain full and milky for many months. Also the ears might be pulled in August and, by tying a string loosely around the small end to prevent the husks from drying away from the ears, they might be laid away on shelves and kept moist and suitable for boiling for a *year or more*. (The italics are this present writer's). No need of a canning factory or a freezer in those days!

Crosby. Crosby was introduced by Josiah Crosby of Arlington, Massachusetts, in 1860. He is reported as an eccentric bachelor, a truck farmer who was much interested in plant breeding as an avocation. The variety Crosby, though not so productive as Stowell's rated higher in quality.

In the above discussion we have considered only mutations of *indentata*. Theoretically there would seem to be no reason why sugary genes should not occur in flint corn also. We have conducted an extensive correspondence with

students interested in breeding flint corn, but have not learned of a single observed mutation. The plant population of the flint corn areas is much less than that of dent corn. The soil and climate of the corn belt may also be a factor which causes these rare breaks from the type.

Golden Bantam appears to be a flint mutation, inasmuch as Bantam when crossed with dent produces a flint.

In the light of present-day evidence, it would appear that sugary genes of field corn may have appeared at infrequent intervals from the time maize was first introduced into North America.

Previous to the advent of the white man they played no significant role as a source of food supply.

In modern times, the great majority of such mutations have been regarded as a contamination and discarded. Thus they disappeared as suddenly as they came, "unheralded and their praises unsung".

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Utilization Abstract

New Perfume Plants. Bedouin Arabs of Palestine, Syria, Transjordan and other countries in the Near East perfume their camel cloth tentage with aromatic wild plants of those areas, but industrial exploitation of these plants has so far been overlooked. This is the opinion of the author who has made botanical collections in those regions during the past two years for the British Museum, local herbaria or for the Army's Middle East Biological Scheme.

"One of the most highly fragrant of these essential oil plants is the thyme-leaved savoury, *Micromeria serspyllifolia* (M.B.) Boiss., whose tall, powdery grey or glaucous stems with their small leaves bear large heads of small white flowers with a remarkably strong odour like a 'deep' peppermint scent. Throughout the whole length of summer this scent drenches the great forestry of Bab el Wad, the gate to the hills to Jerusalem on the road from Jaffa to the capital of Palestine. Even dead plants retain this strong odour, and a single specimen will saturate the whole of a plant collection with its fragrance, and the hands of him who gathers it".

Acacia Farnesiana, well known to the perfume industry, has been successfully planted along the main Jaffa road, and on the coastal plain of Palestine is being extensively planted as a hedging around orange orchards in lieu of the prickly pear cactus formerly used. Elsewhere *Acacia longifolia* is responsible for the aroma of the hillsides.

Other heavily scented species of the area are yellow and white mignonettes (*Reseda lutea* and *R. alba*, resp.), three-lobed sage (*Salvia triloba*), *Teucrium creticum*, *Salvia graveolens*, *Phlomis viscosa* and *Origanum syriacum*). (E. Hardy, *Am. Perf. & Ess. Oil Rev. 57: 201. 1951*).

Utilization Abstracts

Australian Kelp. The Commonwealth Scientific and Industrial Research Organization of Australia has five scientists—two in Western Australia, and one each in New South Wales, South Australia and Victoria—studying the possibly greater utilization of Australia's kelp beds. At Port Arthur, Tasmania, *Macrocystis* is gathered and dried on racks for shipment to Britain to be tested for the making of alginate, and at Fremantle, in Western Australia, a meat and fish-canning firm is preparing agar from seaweed. "Alginate is widely used in the making of certain textiles and in making ice cream, milk jellies and many other things. Agar is also an edible jelly with many other uses, particularly in food canning". (*News release from News & Inf. Bur., Canberra, Australia*).

Broom Fiber. The Italian press has been urging that a native fiber industry be revived, based on the native broom plant, *Spartium junceum*, which, Pliny tells us, was used by the Romans to bind vines to their supports. "Andrea Mattioli, in the 16th century, tells how this fibre was used for ropes and other articles for ships and in making a coarse cloth called 'carmignolo'. Later writers have also referred to the fibre", and in many parts of Tuscany, Umbria and Calabria local use of it has never completely died out. (Anon., *Fibres 11: 34. 1950*).

Hibiscus Fibers. "Fibres derived from *Hibiscus*, a genus of plants of the mallow family, are seldom long out of the news, although the fulfilling of the commercial expectations entertained with regard to them takes a very long time and have yet to be realized. Rosella, majagua, the Indian mallow, cadilla and sida have all had their periods of prominence, as has also okra—better known for its edible properties. Latterly, it has been the turn of kenaf, where perhaps the most determined of all efforts to prove the industrial value of hibiscus fibres is now being made".

"The Indian Central Jute Committee remarks of 'mesta' that this is the most important substitute for jute in India at present, and the one that could be developed most rapidly. The Committee identifies mesta with *Hibiscus cannabinus*—that is with kenaf. We find the claim rather confusing. Mesta or meshta, as it is more commonly known, is to us not *Hibiscus cannabinus* but *Hibiscus ferox*. Notoriously, fibre nomenclature has a knack of getting out of bounds on the slightest provocation; and so it would be as well to clear up the matter as soon as possible". (Anon., *Fibres 11: 266. 1950*).

California Essential Oils. Six years of experimental production of essential oils in California, reported at considerable length in Economic Botany (Jan.–March, 1950), "have demonstrated definite potentialities for a varied essential oil industry in California, and have been concerned with extractives of the following plants: California bay tree, foenugreek, rose geranium, sweet basil, summer savory, clary sage, rue, yucca, spearmint, coriander, labdanum, dill, palma rosa grass and vetivert. (A. Katz & A. Seldner, *Am. Perf. & Ess. Oil Rev. 57: 357. 1951*).

African Peanut Scheme. In the Jan.–March, 1949, issue of Economic Botany attention was directed to a very ambitious scheme of the British Government to meet the world shortage in vegetable oils by growing peanuts, or groundnuts, on a large scale in East Africa. By the end of June, 1950, crops were harvested on somewhat more than half of the 83,000 acres under cultivation, including 1,500 long tons of peanuts, 1,800 tons of sunflower seeds, 850 tons of corn and 180 tons of sorghum. This third-year showing was so poor that "in the summer of 1950 the British Food Minister announced in the House of Commons that attempts to produce large quantities of peanut oil in East Africa would be given up and that the project would be turned into a plan for colonial development with a varied agricultural content". (A. D. Angelidis, *For. Agr. 15: 106. 1951*).

Sugar-cane Wax. Limited quantities of sugar-cane wax are now being manufactured in Gramercy, La., by S. C. Johnson & Son, Inc., and the Cuban American Sugar Co. (*Chemurgic Digest 10*(*5*): *18. 1951*).

BOOK REVIEWS

American Wildlife and Plants. A. C. Martin, H. S. Zim and A. L. Nelson. x + 500 pages; illus. McGraw-Hill Book Co. 1951. $7.50.

During the past 65 years investigators of the U. S. Fish and Wildlife Service have assembled an enormous amount of data concerning the food habits of more than 300 species of birds and mammals which rely upon some 290 genera of plants for sustenance. In this volume, with more than 700 illustrations, these data are analyzed and presented in an astoundingly detailed fashion regarding not only the food habits of every animal concerned but, in addition, with respect to every genus of plant and the role it plays in sustaining the wildlife of the country. Apart from the introductory portion of the book, 239 pages are devoted to birds, mammals, fish, amphibians and reptiles, and to the various kinds of both animal and plant food upon which they feed; 190 pages to the genera of plants and the animals that feed on them. The comparisons that can be made on the basis of all these data are endless, and it is therefore particularly satisfying to find that the concluding chapter of ten pages is devoted to " Wildlife Plants Ranked According to Their Value ".

British Plants and Their Uses. H. L. Edlin. viii + 152 pages; illus. B. T. Batsford Ltd. 1951. 15 shillings.

Here is a moderately sized book so replete with excellent illustrations and information on the utilization of plants in one relatively small portion of the world that a reviewer is at a loss to select any one part for citing or particular mention. In it the author has provided very interesting reading concerning some 450 kinds of plants in Britain, and has arranged those accounts, not according to any taxonomic scheme but into utilitarian groups. Timber trees and edible fungi are not at all considered, but with respect to all other plants the aim of the " book is to review the whole range of useful plants, both wild and cultivated, that flourish to-day in Britain ". Present day uses are of course considered, but " bygone uses and rare plants exploited in but a few parts of the country have claimed equal space with more familiar crop plants, for to the student of folk lore and history it is often such unusual information that proves the most valuable ".

There are chapters on the heathers and other plants of the heathlands, on those of the grasslands and mountain pastures, of lowland pastures and meadows. The four grain crops commonly grown in Britain—wheat, oats, barley and rye—have their chapter, followed by one on straw, rush, reed, sedge and marram. Root crops and tubers, fruit trees and berry bushes, fiber plants, drugs, dyes and condiments receive their due consideration, as well as other groups that in the past or in recent times have in some way served the people of Britain.

An index renders the book valuable as a reference work, but it is the readability of the text and the human angle of the treatment that particularly make it worthy of careful reading.

The Art of Cooking with Herbs and Spices. Milo Miloradovich. xvi + 304 pages. Doubleday & Co., Inc. 1951. $2.95.

ECONOMIC BOTANY is hardly the place to review a cook book, but this one merits at least mention here because in discussing the uses of herbs and spices in an apparently very comprehensive manner the author also gives considerable information on the plants themselves. Their common names, scientific names, regions of production and various other bits of information are included. The botanical reader may be annoyed at times by the confusion on the part of the author between family, generic, specific and varietal names, but proper distinction between these categories perhaps should not be expected in a book essentially so far afield from the pedantry of scientific nomenclature.